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# **VALIDATION OF POLARIMETRIC RADAR SIGNATURES USING THE 2D-VIDEO DISTROMETER**

**Colorado State University**

**V.N. Bringi and J. Hubbert**

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## Abstract

The CSU-CHILL radar (a National Science Foundation supported facility) is a state-of-the-art weather radar operated by Colorado State University. It is the only S-band radar available to the public sector that is capable of measuring the full scattering matrix of a weather target. Critical to the evaluation of polarimetric measurands is the gathering of reliable, accurate ground truth. This was accomplished in part via the mobile deployment of the 2-D Video Distrometer manufactured by Joanneum Research of Graz, Austria, a non-profit organization, during the the period 10 June to 10 August 1996.

During this period the van "Austria", in which the distrometer is deployed, made more than 20 successful storms intercepts in conjunction with with the CSU-CHILL radar. This distrometer records two views of all hydrometeors that pass through its measurement area (about  $10\text{ cm} \times 10\text{ cm}$ ) through use of two CCD (charge coupled device) line scan cameras. The true vertical velocity of the hydrometeors is also measured. This makes possible the calculation of very accurate equi-volumetric spherical diameters, size distributions, and particle non-sphericity and makes it possible to distinguish between rain, hail, graupel and snow. It is the only currently available ground based distrometer that has these capabilities. This information can be used to calculate the radar measurands via sophisticated scattering models thus validating the actual recorded radar data.

Contained in this final report are a general description of the the distrometer, operating procedures and a compilation of representative plots of distrometer data gathered of those days. Specifically, the rainrate as a function of time for the events and representative drop size distributions are given. One general conclusion is that for convective rain events, the drop size distributions are frequently are not Marshall-Palmer in character as is typically assumed in the literature. The

larger particles ( $D_{eq} \geq 4mm$ ) frequently occur in greater concentrations than what is predicted by the Marshall-Palmer model. Since reflectivity measurements are very sensitive to larger particles, rainrate estimates based on empirical rain-reflectivity relationships will vary tremendously, i.e., similar reflectivity measurements can correspond to widely varying rainrates. Thus, the data sets contained in this report demonstrate why rainrate estimates base only on reflectivity will likely fail for convective precipitation.

### **Introduction:**

Research Experience For Undergraduates (REU) is a program sponsored by the National Science Foundation (NSF) where students can assist Professors, out of the classroom, in various fields and gain valuable experience in labs and on the field. The Electrical Engineering REU this year was sponsored in collaboration with the Department of Electrical Engineering at Colorado State University to design and test various types of instruments that could be used to study the Thunderstorms in Eastern Colorado. There were three Chase Vans used in which these instruments were mounted.

We were involved with the Chase Van Austria. This van got its name from the Austrian instrument mounted inside. Austria, as seen in picture 1, is a 1978 Dodge Ram Sportsman that is equipped with a 2D Video Distrometer (from Austria) and 2 Personal Computers (known as **Back PC** and **Front PC**), and a GPS (Global Positioning System) tracking system. All the power needed to run these instruments is provided by two 12 Volt batteries and an inverter. All the digital data is first collected by the back PC and is then sent to the front PC every 3 seconds where the data is stored.

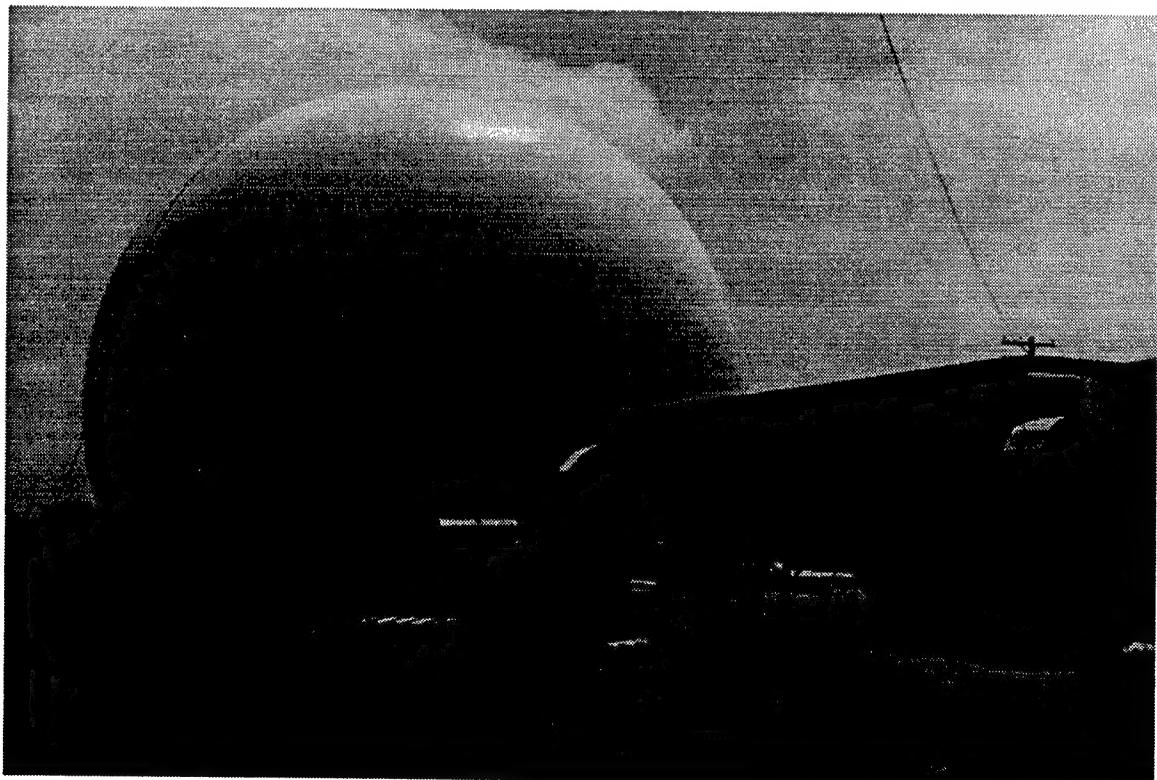


Picture 1: The infamous CHASE VANS.

## **CSU-CHILL Polarimetric Radar:**

### ***Radar Description:***

The CHILL radar has a historic past as it is one of the first radars to utilize polarization diversity. The radar was originally designed and constructed jointly by the University of Chicago and the Illinois Water Survey under the Guidance of Mueller and Atlas. In 1990, the CHILL radar was moved to its present location, outside of Greeley, Colorado, and is now used exclusively as a research radar operated by the Colorado State University under the sponsorship of National Science Foundation. It is a fully Polarimetric S-band radar that can alternately send two Orthogonally polarized signals and simultaneously receive the co- and cross-polarized signals. With recent upgrades made to the radar it now ranks as one of the top radars of its kind.



Picture 2: CHILL Radar

Table: System Characteristics of the CSU-CHILL Radar

Antenna	
Type:	Fully steerable, focus parabolic reflector
Size:	8.5 m
Feed:	Scalar horn
3 dB beam width:	1.0 degrees
Directivity:	45 dB
Sidelobe level (any $\phi$ -plane):	<= -27 dB
Cross-pol. Level (any $\phi$ -plane):	<= -30 dB
Polarization radiated:	Horizontal or Vertical
Transmitter	
Type:	Klystron, modernized FPS-18
Wavelength:	10.7 cm
Peak Power:	700 - 1000 kW
Pulse Width:	Steps of 0.1 $\mu$ s to a max of 1 $\mu$ s
PRT:	800 - 2500 $\mu$ s
Max. Unambigu. Range:	375 km
Max. Unambigu. Velocity:	+ - 34.3 m/s
Receiver	
Noise Figure:	0.7 dB
Noise Power:	- 114 dBm
Typical Band Width:	750 kHz
Transfer Function:	Linear
Dynamic Range:	90 dB, 0 - 60 dB IAGC in 12 dB steps
Data Acquisition	
Signal Processor:	SP20 made by Lassen Research
Number of Range Gates:	64 - 2048
Range Gate spacing:	.2 $\mu$ s or 1 $\mu$ s
Sampling Rate/avg. option:	under micro-code control
Video Digitizer:	12-bit, in the SP20 input card for I,Q & logP
Time series capability:	
Variable Available	
<ul style="list-style-type: none"> <li>• Reflectivity at H polarization (<math>Z_h</math>)</li> <li>• Differential Reflectivity (<math>Z_{dr}</math>)</li> <li>• Mean Doppler Velocity (<math>v</math>) and Spectral Width (<math>\sigma_v</math>)</li> <li>• Differential Phase between H and V states (<math>\psi_{dp}</math>)</li> <li>• Copolar Correlation Coefficient (<math>\rho_{hv}(0)</math>)</li> <li>• Linear Depolarization Ratio (LDR)</li> <li>• Doppler Spectra from FFT processing</li> <li>• I, Q and logP for every pulse in time series mode (up to 150 gates)</li> </ul>	

Courtesy: Two Year Interim Report by John Beaver, CSU

## The Austria Van

The 2D-Video Distrometer, commonly called the Austrian instrument, was designed and built by the Joanneum Institute for Applied Systems Technology Graz, Austria. It has been loaned to Colorado State University by this Institute for the summer to carry out research, and in the process, test the instrument. The main parts of this instrument are:

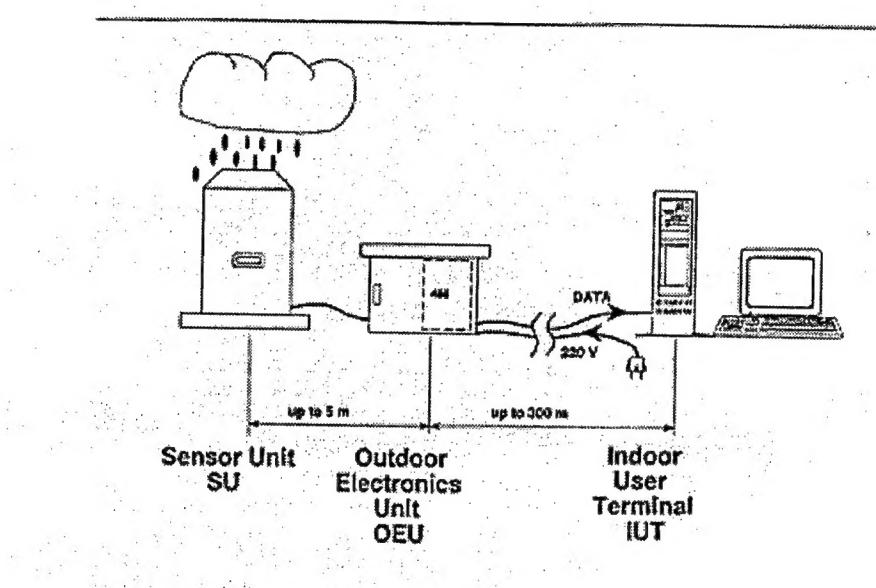
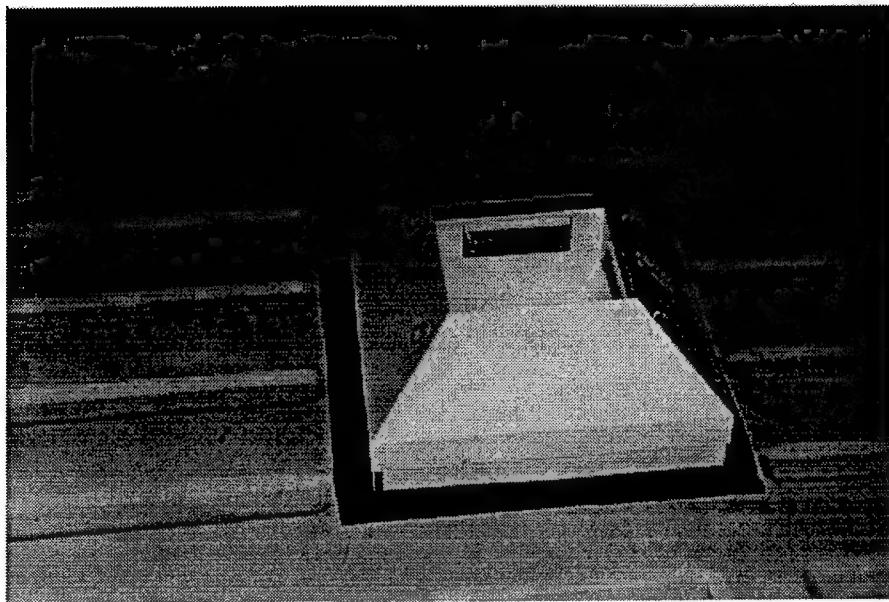


figure 1: Schematic Drawing of the Distrometer

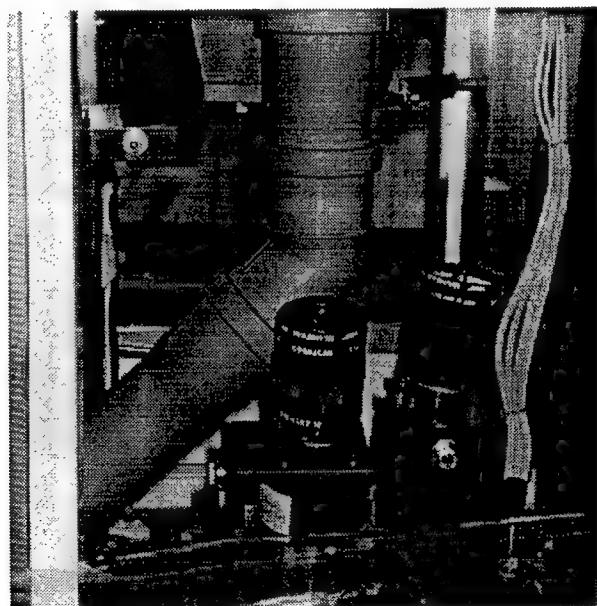
1) **Sensor Unit (SU):**

This unit has been mounted on rubber shock absorbers inside the Austria Van. An approximate opening of 18 square inches has been cut from the roof of the van so that the top part of this sensor can face out. The sensor itself has an opening of 10 square cm through which the rain/hail drops fall into the pipe which rains them out from the small opening on the van floor.



Picture 3: Top view of the sensor unit.

Also mounted in the sensor unit are the two Line Scan Cameras, Two Illumination lamps and the Mirrors. (Detailed functions of these are listed in the software and hardware manuals).



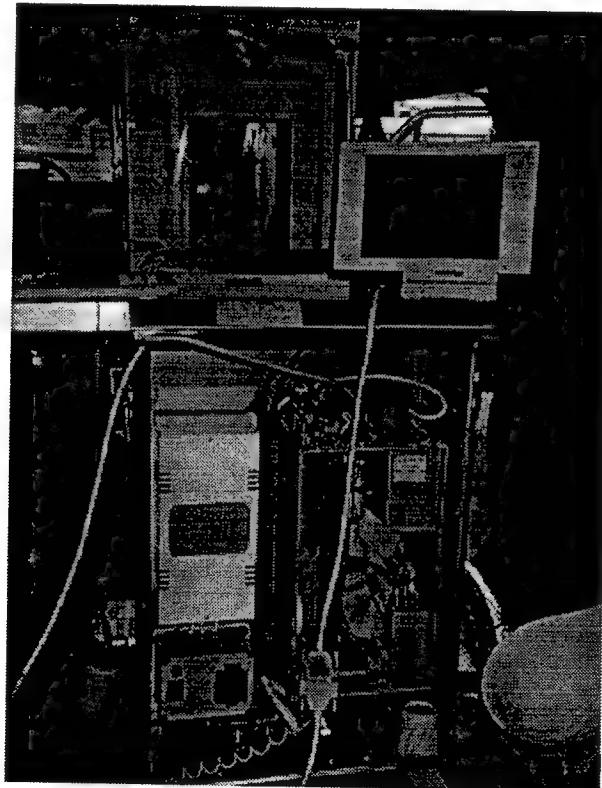
Picture 4: Line scan Cameras

2) **Indoor User Terminal (IUT):**

The Indoor User Terminal consists of a 120 MHz Pentium PC. This is also commonly referred to as the front PC. This has been mounted behind the drivers seat also on rubber shock absorbers. The monitor for this PC has been mounted in the middle behind the front seats on a wooden table. The main function of the front PC is to receive data sent by the back PC, store it and display it online/offline.

A minor modification was made after IUT was received from Austria. A small 200 Megabyte hard drive was installed inside the Front PC so that data could be backed-up after collection for safety reasons.

3) **Outdoor Electronics Unit (OEU):**



Picture 5: The Back PC

The OEU is an outdoor unit, but it has been installed inside Austria in order to make the Distrometer mobile. The OEU has been mounted at the rear end of the van. This unit is a steel box inside which a 133 MHz Pentium PC is mounted. This unit is referred to as the Back PC. This unit is directly connected to the SU. It collects data from the SU using the acquisition program provided by Joanneum Research and sends it to the Front PC in small packets every three seconds. A 50 Ohms coaxial cable is used to transfer pre-processed data from the OEU to the IUT.

## Overall Plan of the Austria Van Setup:

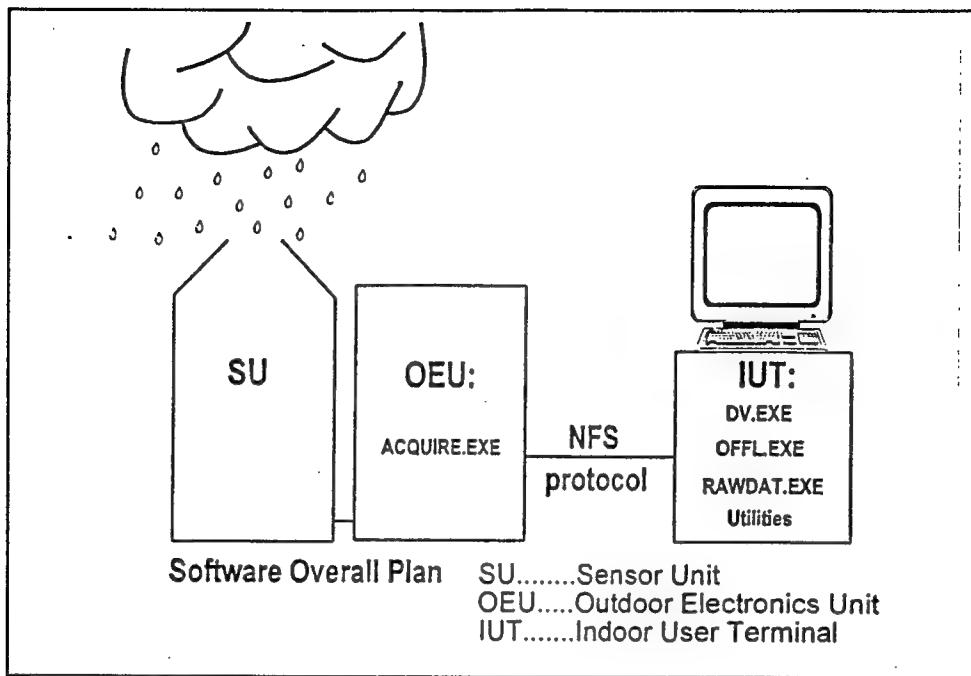


Figure 2: Software overall plan

The overall plan for the 2D-Video-Distrometer software recognizes five main parts:

- Video Control and Data Acquisition:
- Link OEU-IUT: performed via standard NFS protocol.
- Data Storage Manager and Online Display (DV.EXE): This part represents interface to the user.
- Offline Display (OFFL.EXE and RAWDAT.EXE)
- Utilities: several utilities are available for decompressing the recorded data files and for conversion and display of the screendump files.

## GPS Unit:

In addition to the 2D-Video Distrometer there is a Global Positioning System (GPS) in the van. The GPS unit allows technicians at the CHILL Radar site to find the van's exact locations. With the movement of the chase vans, the GPS unit is constantly active and

records the location of the van. A program time and date stamps each entry in a data file containing the latitude and longitude of the van. However, these coordinates mean nothing since all the radar data is centered around the radar. Therefore it is important to convert the Lat-Lon reading to the XY coordinates from the radar to make the post analysis of the data easier and more accurate for the user.

A c code has been written for this conversion and the name of the code is azran.c. The exact code for this program can be found in appendix D of Duncan Halstead's report. It reads from a prompted data file and writes to either standard output or a user defined file. There is a DEFINE statement LINES\_2\_DATA that can be changed to skip bad lines of data, or headers. The program then simply reads until the end of file. When converting the latitude and longitude coordinates, the CHILL Radar has a longitude and latitude of 40.446 degrees and 104.637 degrees respectively, and there are 60.12 nm/degree.

If the format of the data files ever change, all that needs to be modified is the scanf statement that reads in the data. Currently, there is a variable called dummy used to read in the semi-colons between the degrees, minutes and seconds of the latitude and longitude.

### **Principle Of Operation:**

The figure shown below is a schematic drawing illustrating the operating principle of the instrument. The trapezoid black box is the Illumination Device (I.D.), which in principle is an extremely large-diameter optical condenser.

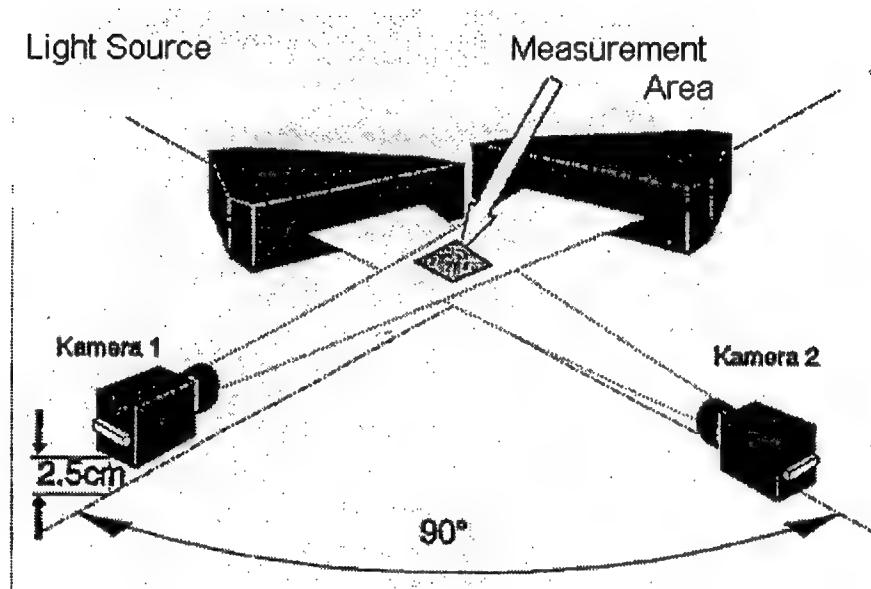


Figure 3: Arrangement of Optical System

Two line scan cameras are directed towards the opening of these illumination devices. The optical system is designed in such a way that (seen thru the camera lens) the slit of the I.D. appears as a relatively even illuminating background of extreme brightness.

To the cameras, any particle falling thru the beam of the light will appear as a dark silhouette against this bright background.

In reality, each of the two optical paths contains two mirrors that are used to "bend" the beam. These are left out here in order to simplify the drawing.

## **Operating Procedure for Austria:**

- 1) Take out the foam from the top opening of the SU.
- 2) Turn on the OEU. Wait until the prompt shows up. At the prompt type OPER.  
(Note: This command has already been written in autoexec.bat and does not need to be typed if turned on from the inverter)
- 3) Once OPER is executed the back PC should go through some processes (like reading the parameters from the file acquire.par) and at the end it should read "data acquisition running"
- 4) After Data acquisition starts running, turn on the IUT using the switch on the Front PC. Two options will appear on the screen:

- 1) Mobile
- 2) Docked

When collecting data the first option should be used, ie. Mobile (The second option is used when uploading saved data to one of the Sun work stations at the Radar Lab. This will be described later on in the report)

- 5) After the selection is made the screen should read c:\2d-video\oper. At this point type DV. This will take you into an online display.
- 6) Inside this online display, change the time window to the current time. Make sure that the current time is put in as the data collection is appended to the same file.
- 7) Once the time is sent, click on run and sit back to see the spectacular work which is being done by the distrometer. Do not forget to take good notes as they are the key to good analysis which leads to good reports.

- 8) Once the rain event stops, hold escape on both PC's to come out of acquisition.
- 9) Now is the time to backup the data which has been collected. On the prompt type:

backit xxx y

where:

xxx is the number of days which have passed in the year since January 1 (Julian Date). If in doubt look at the Julian date calendar in the van.

y is the event number of the day. Make sure that the first event of the day is 2, second 3, third 4 and so on.

So the backup procedure for the 5<sup>th</sup> event on July 7, 1996 will be:

backit 189 6

This procedure saves data on drive f.

- 10) To minimize the loss of data we backup the data a second time with the same conventions. The command for this is:

backit2 xxx y

This saves data on drive g.

- 11) Now the system should be turned off and the foam should be put back on.

**Important:** It is very important to remember that DV should not be run unless the acquisition program on the back PC is running. If this is not done it will corrupt the data files. If DV is accidentally hit, the file delete procedure in the 'problems' part should be followed.

### **Problems:**

Sometimes during the collection of data due to unknown reasons the data acquisition hangs up and the front PC freezes. In this case:

- 1) First hold escape to get out of acquisition from the back PC.
- 2) Then try holding escape on the front PC. If this works go to step 4 else go to step 3.
- 3) Reboot the front PC.
- 4) At the prompt type:
  - a) backit xxx y
  - b) backit2 xxx y
  - c) del e:\raw\v96xxx\_1.\*
  - d) del e:\hyd\v96xxx\_1.\*
- 5) Turn off the Front PC and go to step one of the operating procedure.

### **Periodic Backup on the Sun Stations in the Radar Lab at the EE building:**

Periodically all the data collected should be uploaded to the Everest machine in the radar lab so that it can be put on tapes for permanent safekeeping. Follow the procedure outlined below:

- 1) Take the van to CHILL radar.
- 2) Take the coaxial cable from the conference room in the main building. (If in doubt ask Dave)
- 3) Connect the cable to the ethernet card of the front PC.
- 4) Start the front PC and go in to 'Docked', the number 2 option.

5) At the prompt type:

- a) e:\hyd
- b) ftp everest.lance.colostate.edu
- c) enter your user name and the password

At the ftp prompt type:

- a) the directory where you want to save the data for 1996:

cd ~radar/REU/vivek/chill/96data

- b) bin
- c) mput v96xxx\_.\*
- d) lcd ..\raw
- e) mput v96xxx\_.\*
- f) this procedure should be repeated until data for all days is uploaded.

## **Data Processing:**

After the data is collected in the Indoor User Terminal, it can be viewed either online or offline. The online procedure has been discussed in the operating procedure of the Distrometer. There is an offline version of the same software so that the data can be viewed and analyzed at a later date at the user's convenience. The executable for the software is OFFL.EXE, also supplied by Joanneum Research, Austria. The procedure to run this program is listed below:

- 1) Get the \*.hyd file of the date desired to be analyzed from the Sun Station at the radar lab in the EE building.
- 2) Put the \*.hyd in the same directory as OFFL.EXE
- 3) Type: offl v96xxx\_(event number).hyd
- 4) Right now the program is loaded on the Parnassus PC at the radar lab.
- 5) \*.hyd files have a separate directory under c:\schoe\1996\hyd
- 6) To run offl type: offl ..\hyd\v96xxx\_(event number).hyd

### **What can we look at by running the offline version?**

This simple program provides us with a lot of information. It is hard to believe that a small program like OFFL can provide information about:

- a) **Rain Rate versus Time:** The integration interval used for calculating the rainfall rate for this diagram is not a time interval, but a rainfall quantity. The diagram is updated each time a rainfall quantity of 0.1 mm is exceeded. The rainfall rate over the past 30 minutes, counted from the occurrence time of the most recent update, is represented.

b) **Drop Size Distribution:** The diagram is updated each time a rainfall quantity of 0.1 mm is exceeded. This rainfall quantity is used as an integration interval for calculating the DSD. The diameter class width can be set from 0.25 mm to .05mm.

c) **Vertical Velocity versus Diameter:** This diagram shows hydrometer vertical fall velocity versus equivalent diameter. A dot is set for each hydrometer at the corresponding (diameter, velocity) position. The diagram is updated on each hydrometer. In Run-mode, this diagram is cleared whenever 0.1 mm of rainfall is exceeded.

d) **Horizontal Velocity:** Horizontal velocity is derived from the difference between the center pixel position in the first line and the center pixel position in the last line of a particular drop's shadow area. This difference in center pixel positions is made visible by drawing a "drop axis" into the front/side view of a drop. This result is an approximation method to determine the drop's horizontal velocity. It should be pointed out that the horizontal velocity may be precisely calculated whenever the drop's views are divided into two identical halves. A dot is set for each hydrometer at the corresponding (velocity, direction) position.

e) **Oblateness versus Diameter:** This diagram shows drop oblateness versus equivalent diameter. A pixel is set for each drop at the corresponding (diameter, oblateness) position. The diagram is updated on each drop. Oblateness is calculated by forming the geometric mean value of the two height/width ratios, which can be computed from drop front and drop side view.

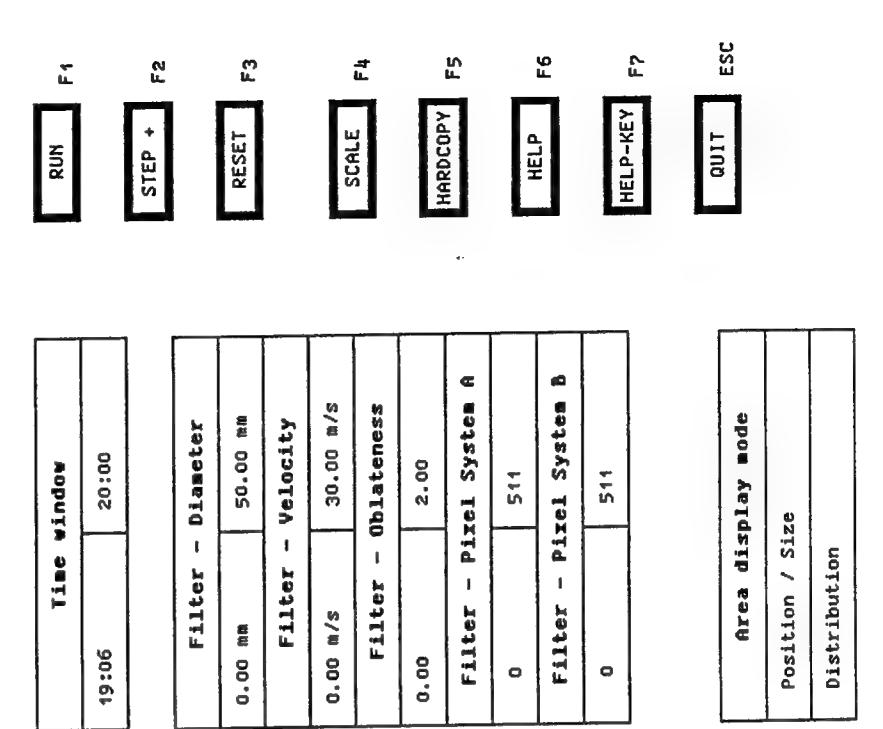
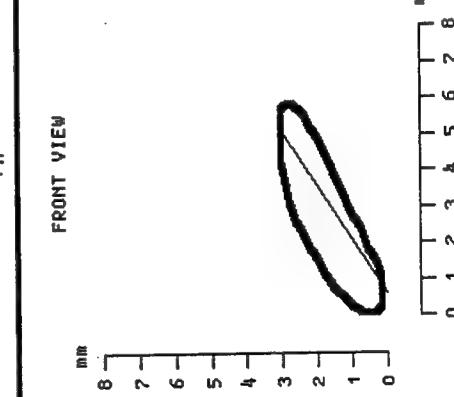
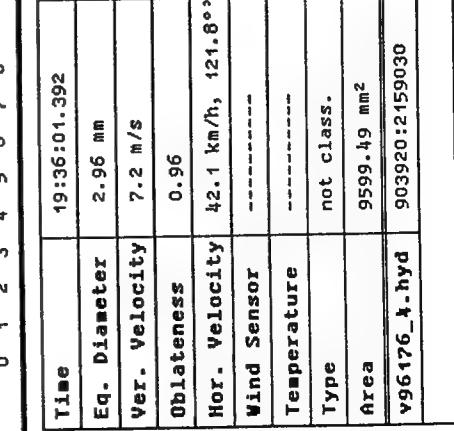
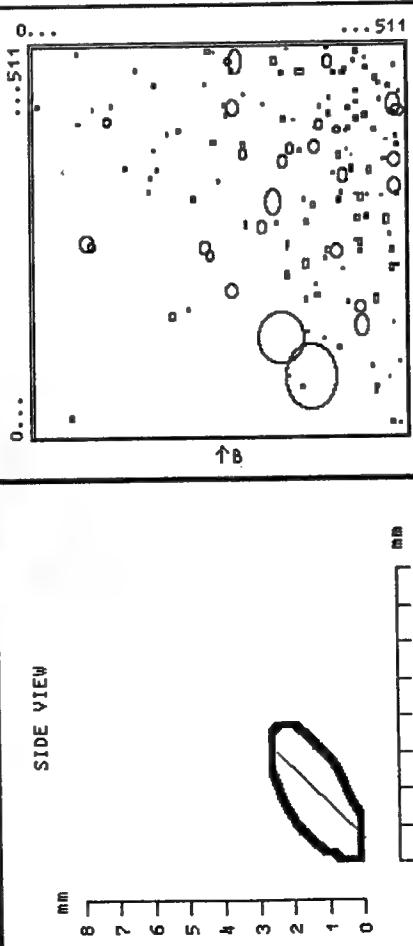
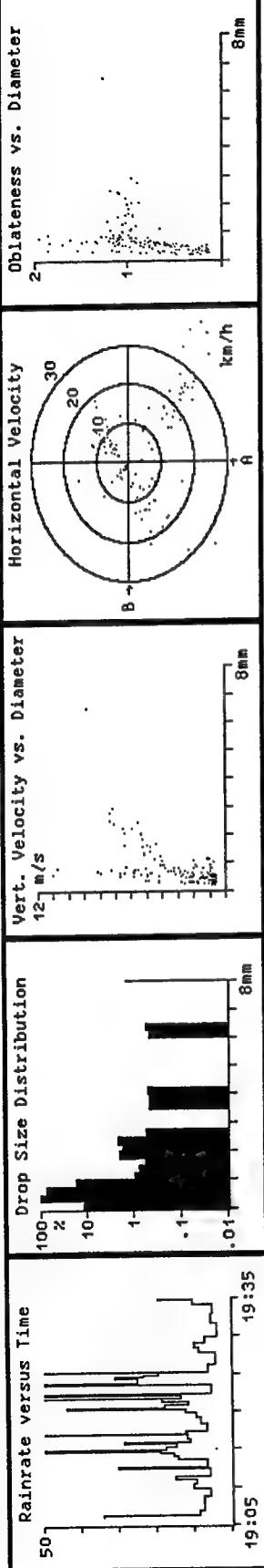
f) In addition to the above we can see each drop as it was scanned.

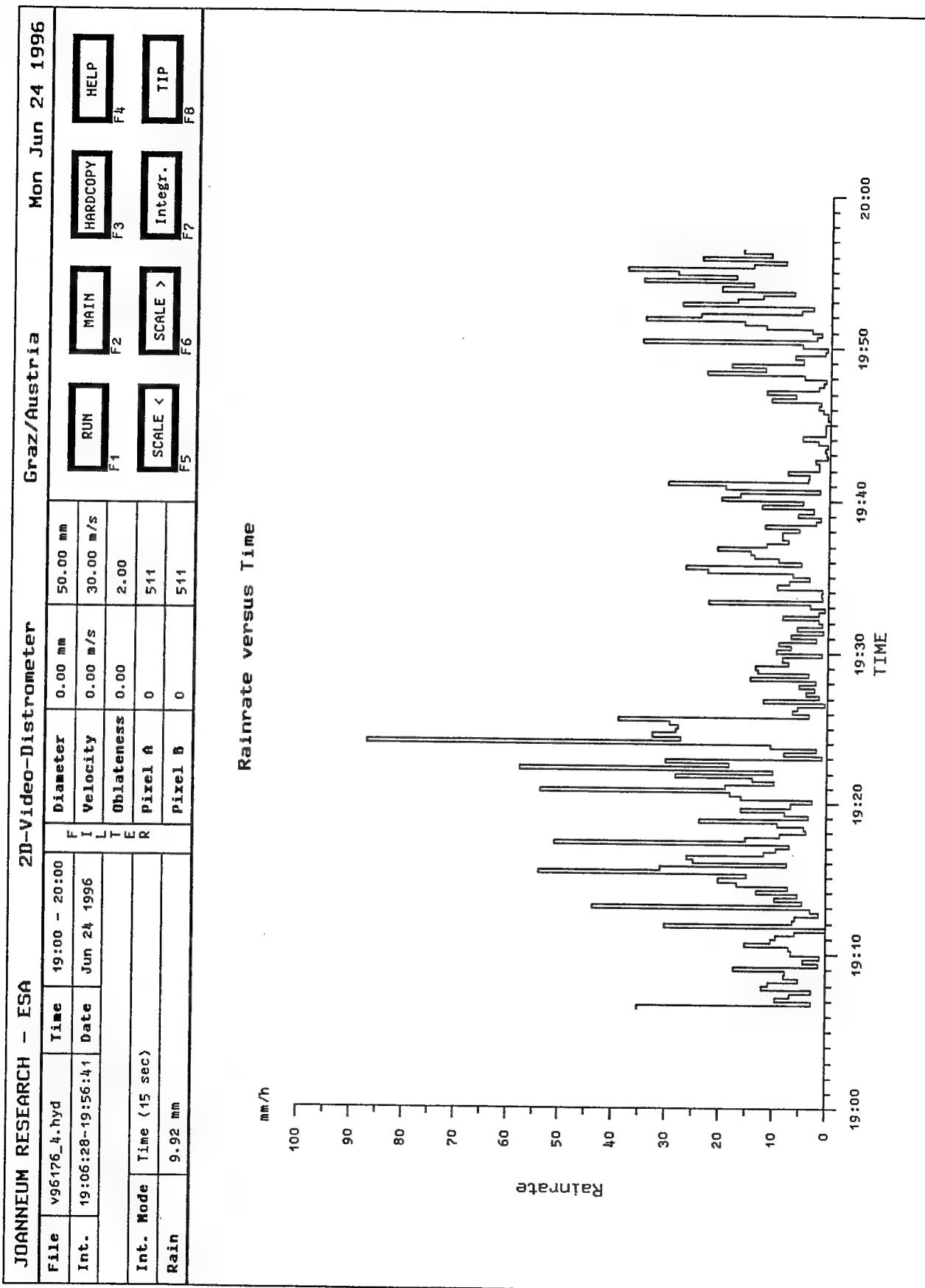
JONNEUM RESEARCH - ESA

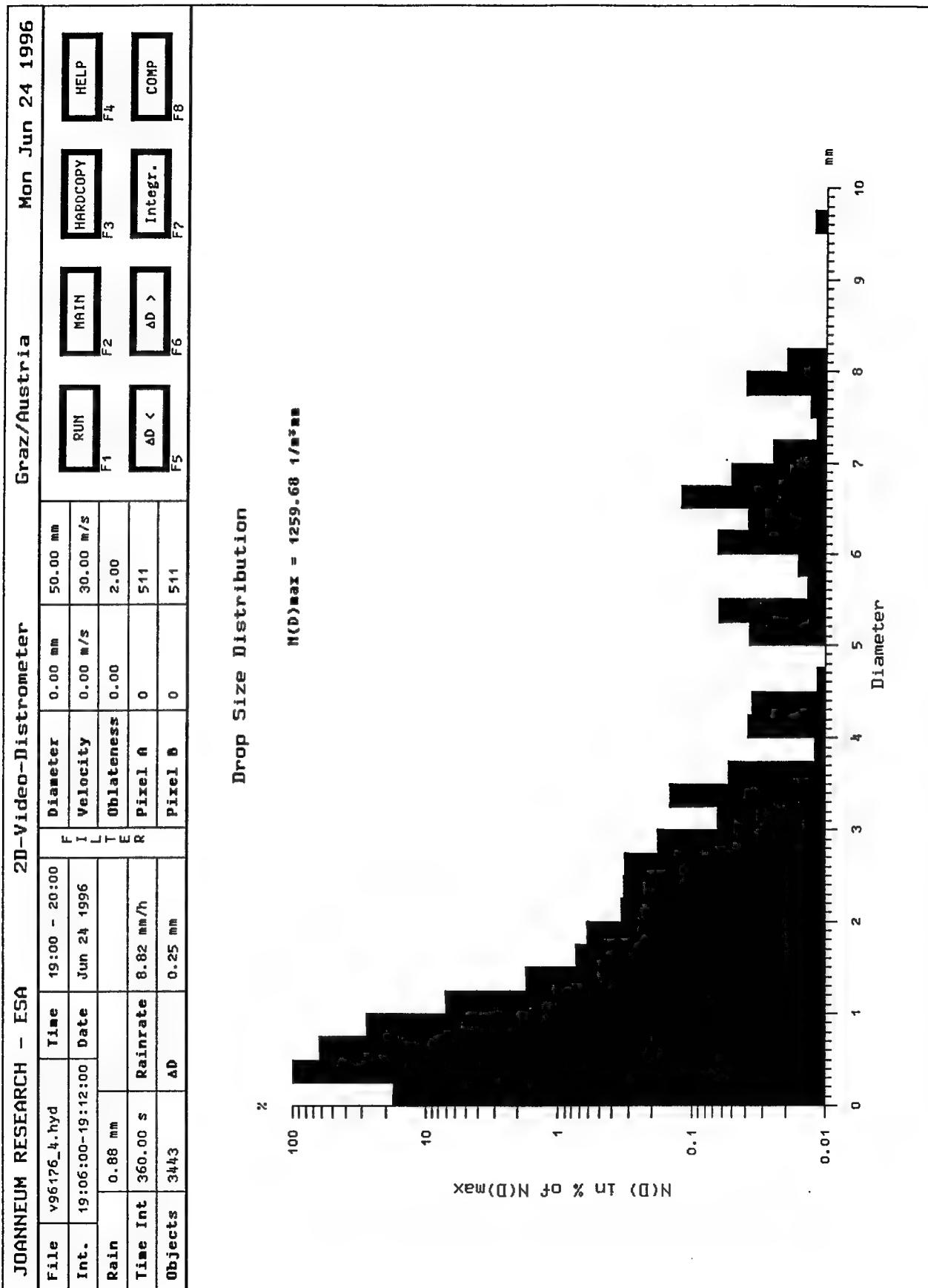
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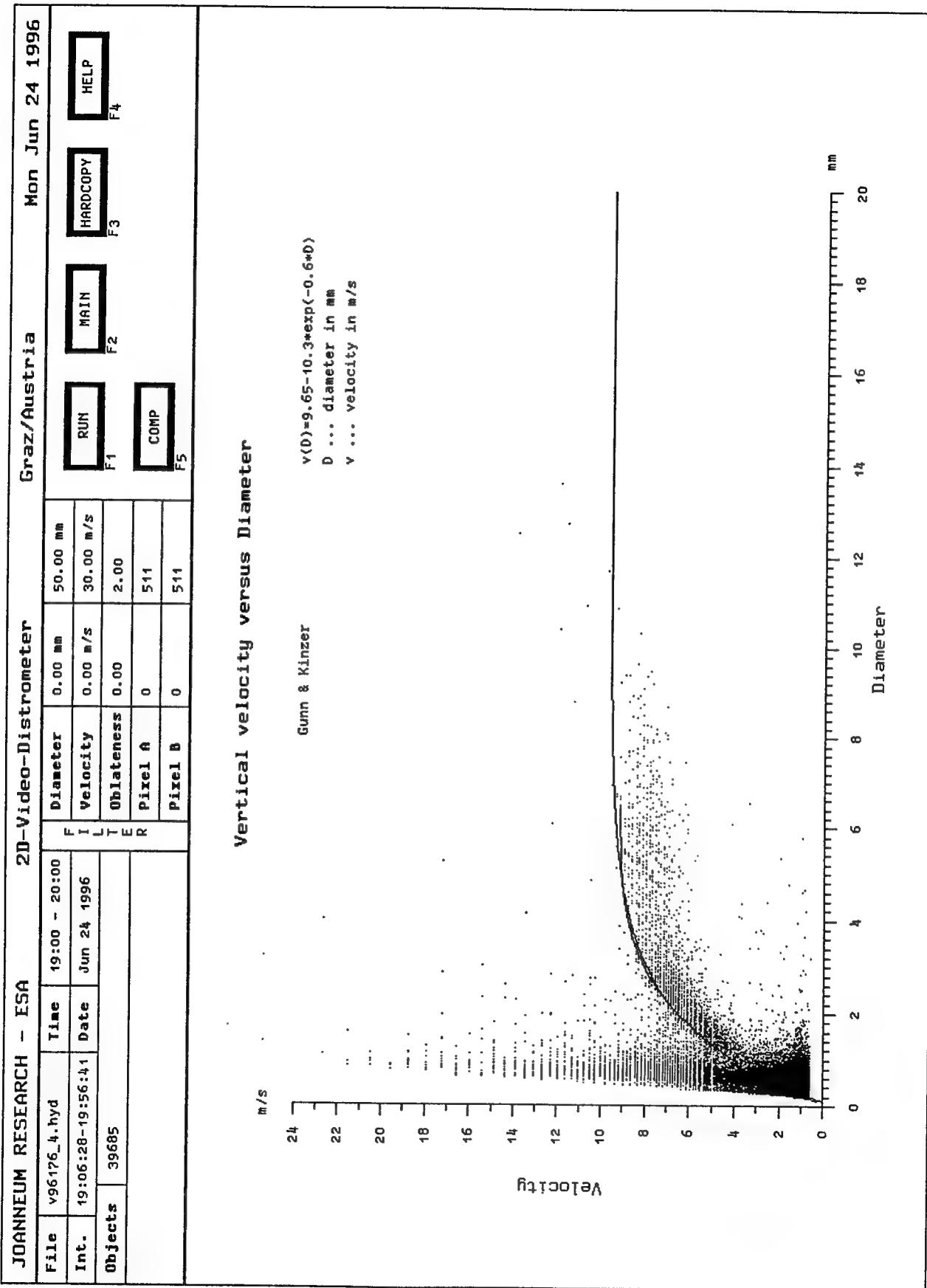
Graz/Austria

Mon Jun 24 1996



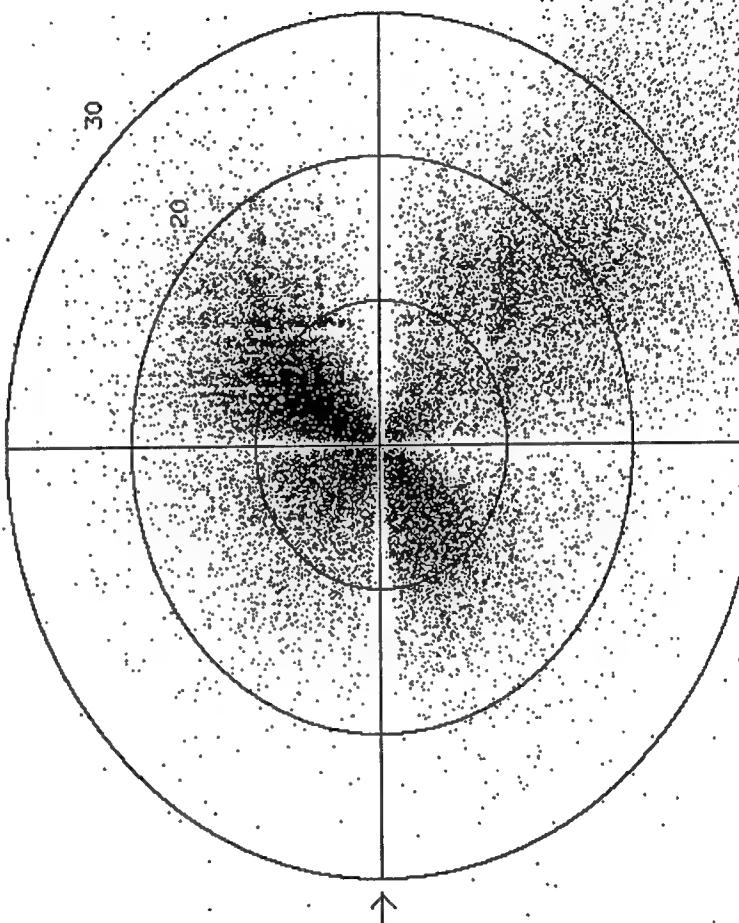






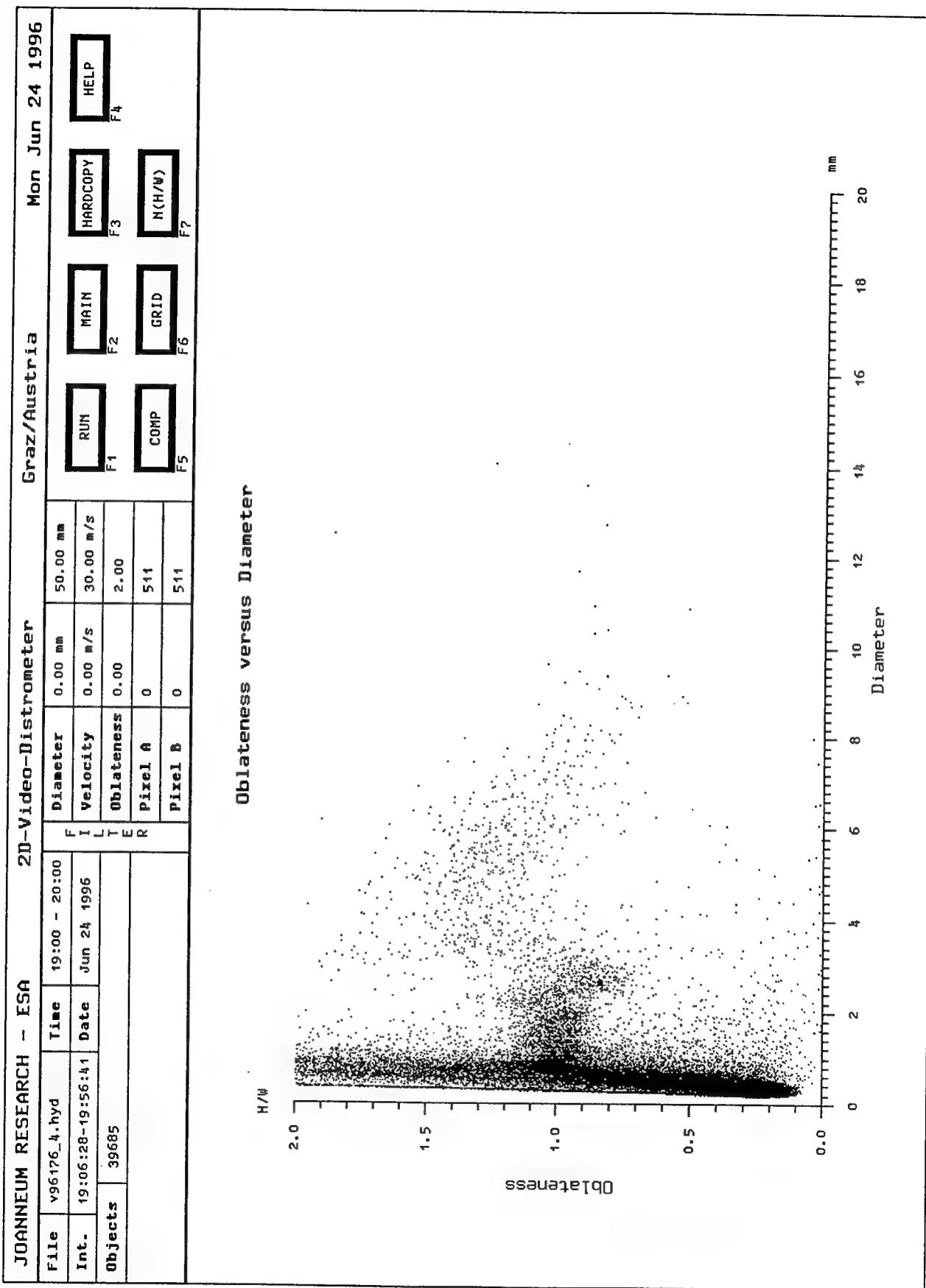
JOANNEUM RESEARCH - ESR						2D-Video-Distrometer				Graz/Austria			
File	v96176_4.Hyd	Time	19:00 - 20:00	Diameter	0.00 mm	50.00 mm	50.00 mm	MAIN	HELP	F1	F2	F3	F4
Int.	19.06:28-19:56:41	Date	Jun 24 1996	Velocity	0.00 m/s	30.00 m/s	30.00 m/s	RUN	HARDCOPY				
Objects	39685			Oblateness	0.00	2.00							
				R Pixel A	0	511							
				Pixel B	0	511							

Horizontal velocity



System B (Side)

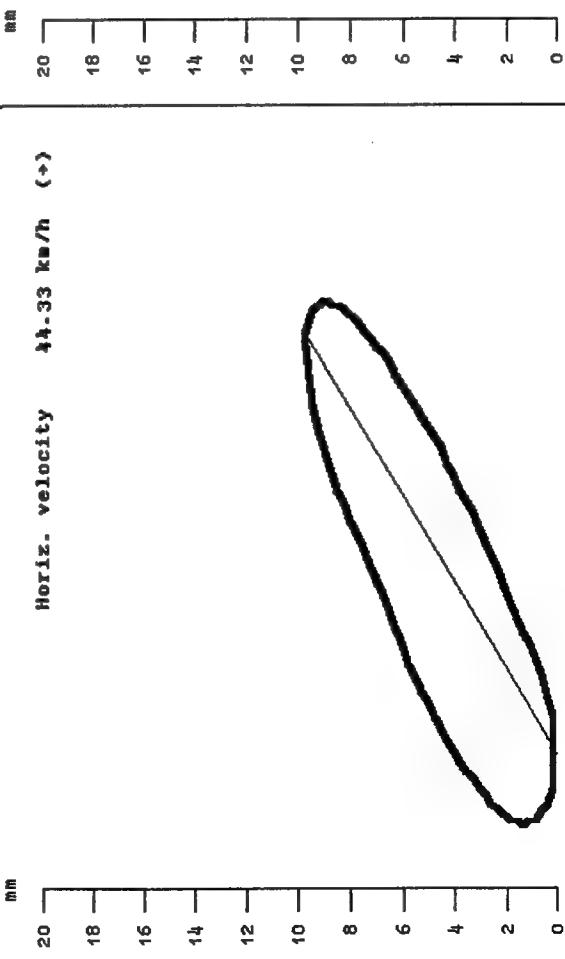
↑  
System A (Front)  
↓  
km/h



JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria				Mon Jun 24 1996			
File	v96176.4.hyd	Time	19:00 - 20:00	Diameter	5.00 mm	50.00 mm		STEP +	MAIN	HARDCOPY	HELP				
Hyd. Time	19:10:33.397	Date	Jun 24 1996	I	Velocity	0.00 m/s	30.00 m/s	F1	F2	F3	F4				
Eq. Diam.	9.66 mm	Velocity	8.45 m/s	L	Oblateness	0.00	2.00								
Obl. ness	1.04	Type	not class.	R	Pixel A	0	511	STEP -	ASCII	CORR	F?				
				P	Pixel B	0	511	F5	F6						

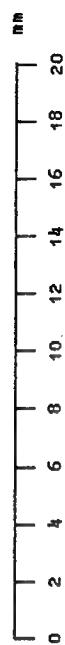
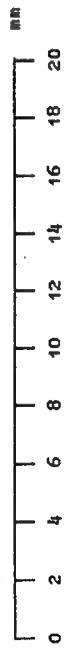
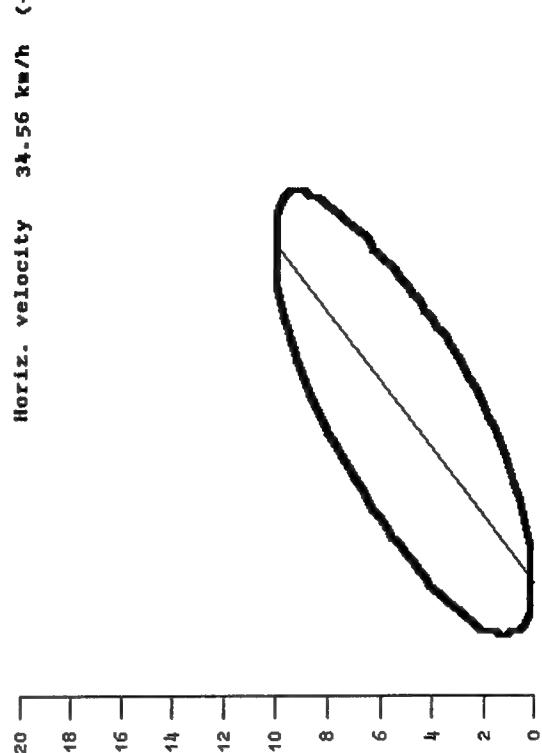
FRONT VIEW  
Oblateness front 1.01

Height front 9.84 mm  
Width front 9.74 mm  
Horiz. velocity 44.33 km/h (+)



SIDE VIEW

Oblateness side 1.08  
Height side 10.08 mm  
Width side 9.35 mm  
Horiz. velocity 34.56 km/h (+)



### **Calibration:**

Every morning before the van is taken out the Distrometer should be calibrated. There are a few steps which should be followed. These steps are outlined below:

### **Plane Alignment Program:**

#### **Purpose:**

PLANE.EXE is a program supplied by Joanneum research to perform the fine adjustment of the optical measurement planes.

#### **Principle of Measurement:**

Precision steel balls of 10.0 mm in diameter are dropped through the measuring area at a great number of different positions. The program records the front- and side-view of these objects and then evaluates the following time differences:

Object appears in camera A - Object disappears from camera A

Object appears in camera B - Object disappears from camera B

Object appears in camera A - Object disappears from camera B

Object appears in camera B - Object disappears from camera A

This results in a system of equations that allow to (very accurately) calculate the plane distance for each ball dropped in a particular position. As soon as enough measurement points are available to calculate reliable mean values, the program calculates the “best fit” plane-equation and displays the measured plane distance at 3

corners of the virtual measurement area. The user can then make corrective adjustments to the mechanical components.

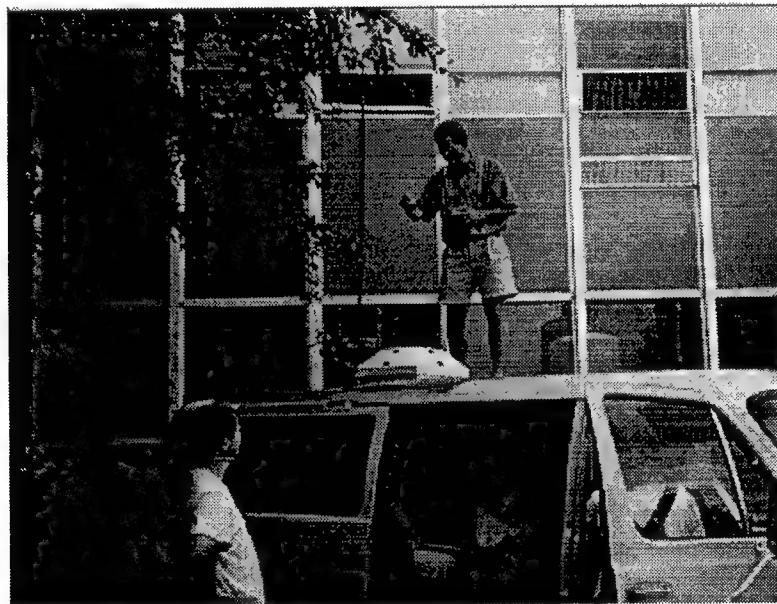
**How to use PLANE.EXE to measure plane distances:**

At the OEU's command prompt type:

*plane*

to start the program. The initialization routines are practically the same as the ones used in the data acquisition program *acquire*.

After initialization has completed, the screen will display a symbolic "top view" of the distrometer orifice. This is oriented "looking from camera A into the respective illumination device".



Picture 6 : Dr. John Hubbert doing calibration

The program now prompts you to throw balls with the message:

***Data acquisition running- Throw balls now.....***

Drop 10 mm calibration balls into the measurement area. The fall height must not be too great. Ideally, drop the balls from approximately the height of the funnel rim (ie some 5 cm above the plane)

Now go on throwing balls keeping in mind the following:

- a) Try not to throw two or more balls at once.
- b) Try to distribute your hits evenly across the measurement area.
- c) Some of the balls will not appear on the screen (the first never shows up), this is because the program performs a number of integrity checks on the raw data and would rather discard a single measurement point than run the risk of using unreliable data.
- d) **DO NOT LOSE THE BALLS THEY ARE 10 US DOLLARS EACH.**

Keep throwing the balls until prompted

*Enough points -> press 'E' to evaluate...*

Pressing the 'E' key will display the plane distance in millimeters at the three corners of the measurement field. A positive value means plane 'A' lies above plane 'B' which is the normal orientation.

#### **Fine adjusting plane distances:**

Use **plane** to measure plane alignment as described above.

Use fine adjustment screws on the camera tilt table to correct plane distances:

- a) Use the long vertical screw to lift and lower the corresponding plane: Turning clockwise will lift the plane as a whole.
- b) Use the short horizontal screw to tilt the plane: Clockwise will lower the left and lift the right side of the plane.

c) The short horizontal screw will never be needed for adjustment.

Check plane alignment again using *plane*. If major mechanical adjustments have been made, it might be necessary to correct the raw video height. Refer to the manual attached.

Repeat the above procedure until average plane distance is:

6.2mm +/- 0.1mm

Put the exact value in the acquire.par file by editing it using the 'b' editor.

---

**APPENDIX A**

**PROCESSED DATA**

**GRAPHS**

Date: June 10, 1996

Julian Day: 162

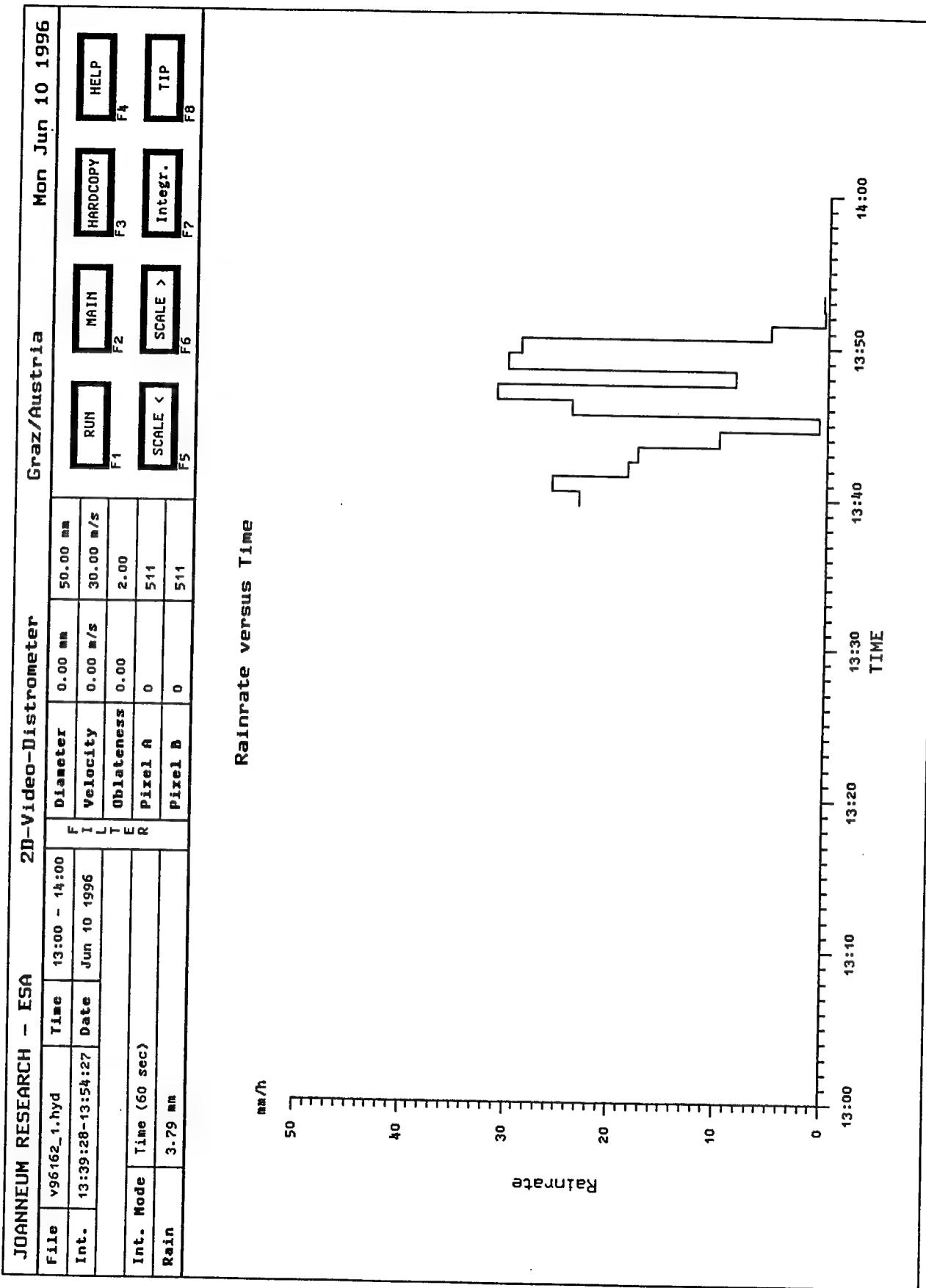
Time: 13:39-13:54

Average Rain Rate: 14.22mm\hr

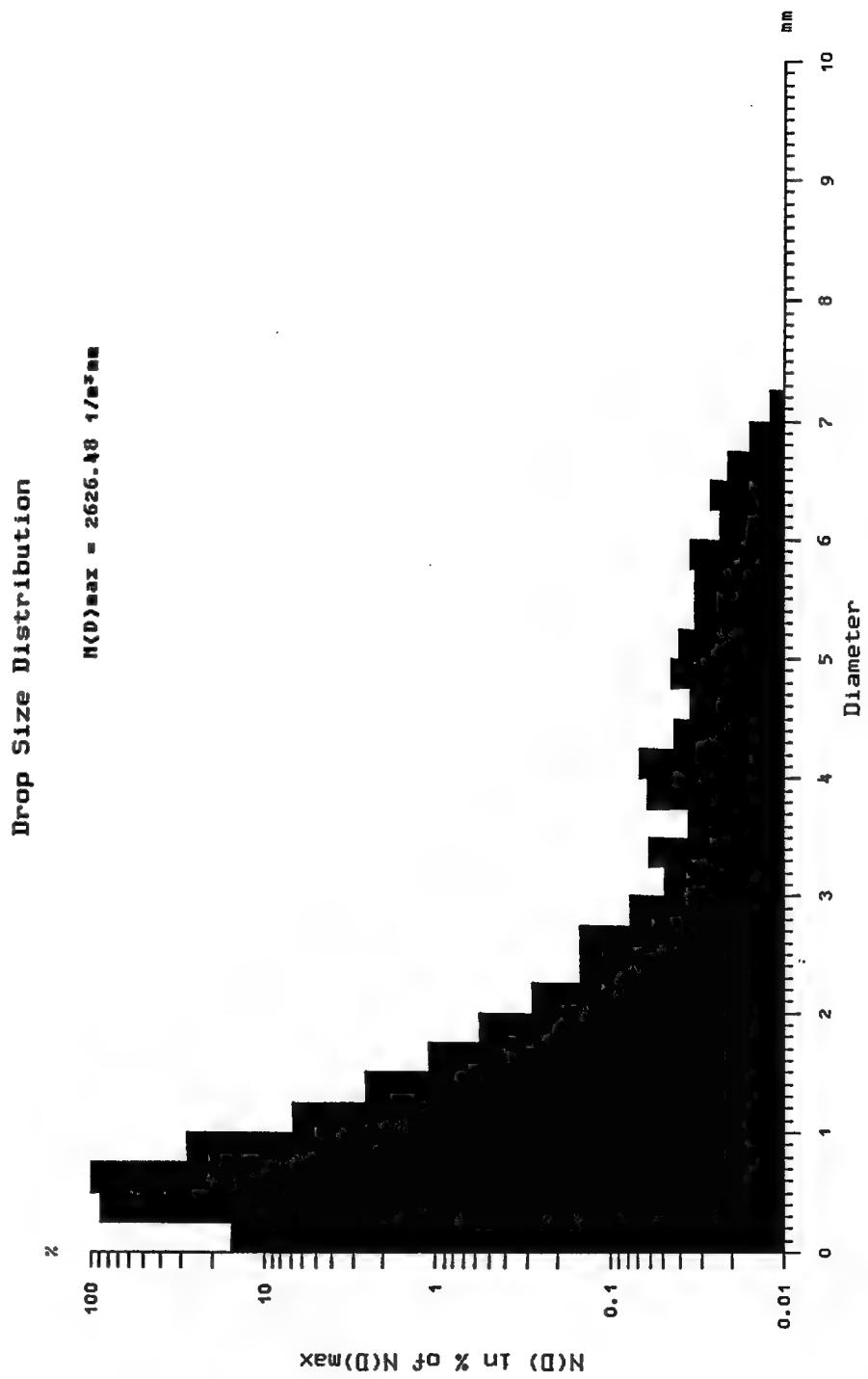
Total Rainfall: 3.79mm

Location: County road 50 & frontage road  
Facing east

Contents: Easterly wind  
Large drops  
Water covered ice particles  
13:47-13:51: small hail

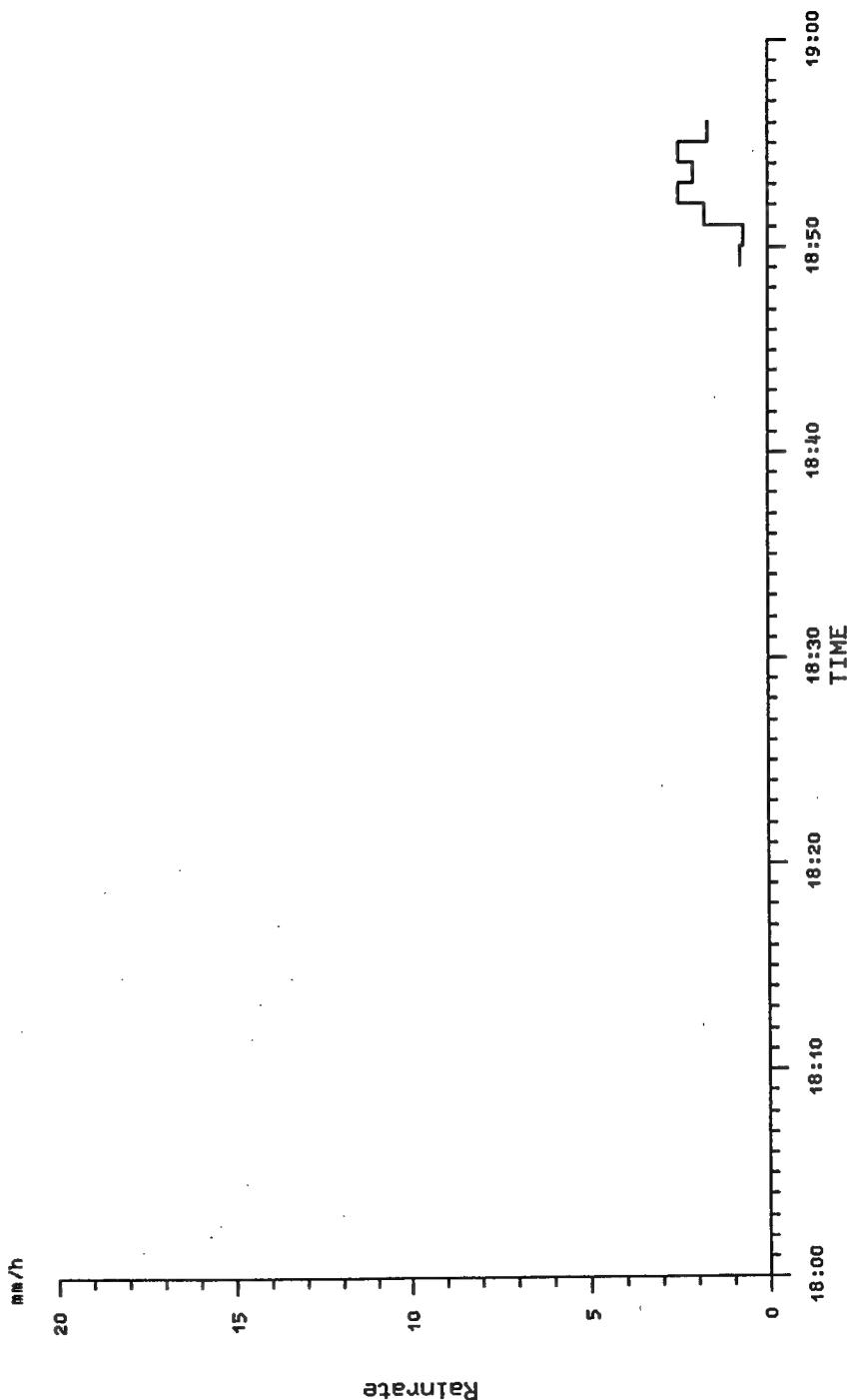


Date: June 12, 1996  
Julian Day: 164  
Event: I  
Time: 18:49-18:56  
Average Rain Rate: 1.76mm\hr  
Total Rainfall: .21mm  
Location: Highway 34 and County road 47  
Contents: light to moderate rain



JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria				Wed Jun 12 1996			
File	v96164_1.hyd	Time	18:00 - 19:00	F	Diameter	0.00 mm	50.00 mm	RUN	MAIN	HARDCOPY	HELP	F1	F2	F3	F4
Int.	18:49:05-18:56:11	Date	Jun 12 1996	I	Velocity	0.00 m/s	30.00 m/s								
				L	Oblateness	0.00	2.00								
				E											
				R	Pixel A	0	511								
					Pixel B	0	511								
Rain	0.21 mm														

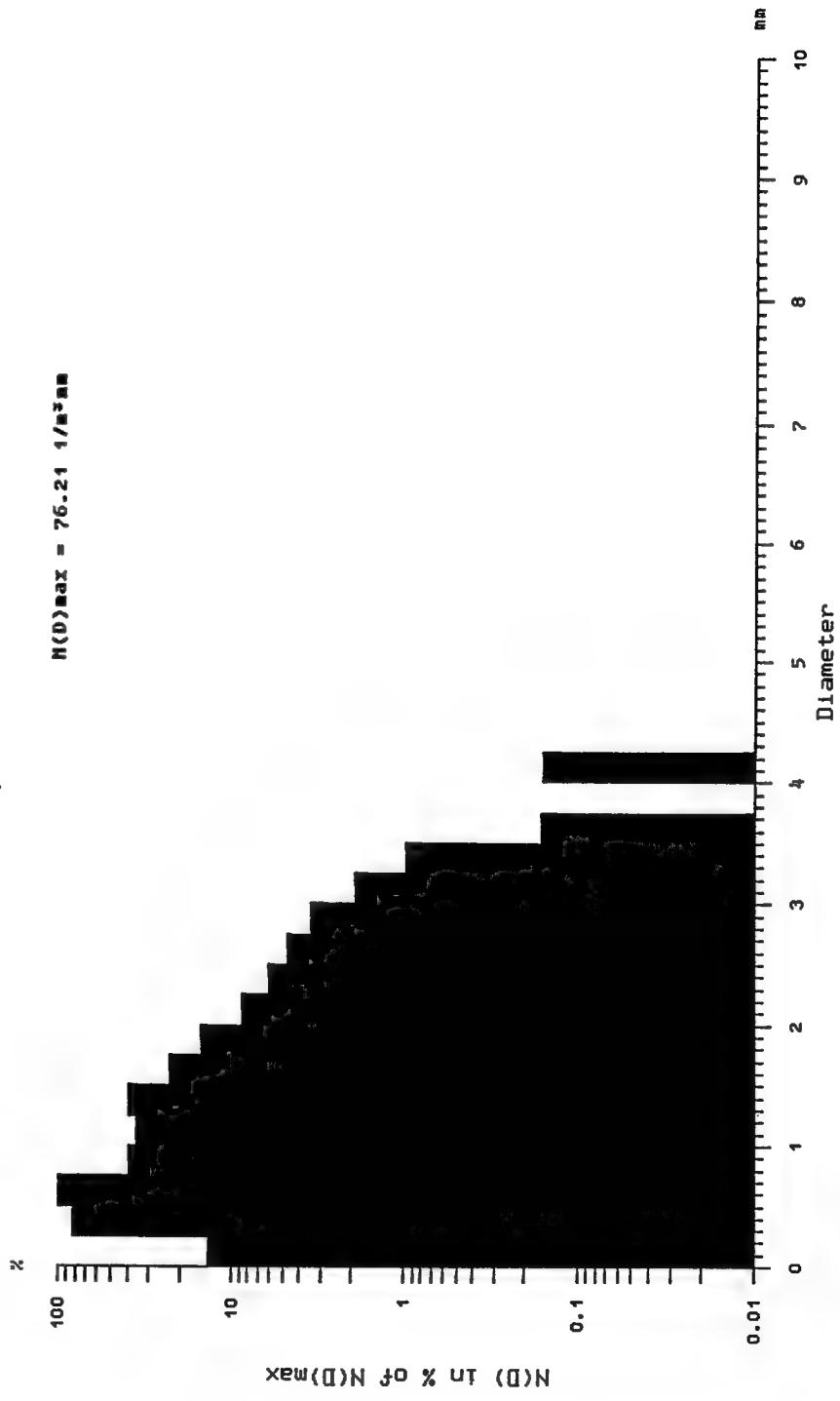
Rainrate versus Time



JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria						Wed Jun 12 1996								
File	v96164_1.lyd	Time	18:00 - 19:00	Diameter	0.00 mm	50.00 mm	100.00 mm	150.00 mm	200.00 mm	250.00 mm	300.00 mm	350.00 mm	400.00 mm	450.00 mm	500.00 mm	550.00 mm	600.00 mm	650.00 mm	700.00 mm	750.00 mm	800.00 mm	850.00 mm	900.00 mm	950.00 mm	1000.00 mm	
Int-	18:49:00-08:56:00	Date	Jun 12 1996	F	Velocity	0.00 m/s	30.00 m/s	60.00 m/s	90.00 m/s	120.00 m/s	150.00 m/s	180.00 m/s	210.00 m/s	240.00 m/s	270.00 m/s	300.00 m/s	330.00 m/s	360.00 m/s	390.00 m/s	420.00 m/s	450.00 m/s	480.00 m/s	510.00 m/s	540.00 m/s	570.00 m/s	
Rain	0.21 mm			L	Oblateness	0.00	2.00	4.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00	30.00	32.00	34.00	36.00	38.00	
Time Int	420.00 s	Rainrate	1.76 mm/h	R	Pixel A	0	511	1023	1535	2047	2559	3071	3583	4095	4607	5119	5631	6143	6655	7167	7679	8191	8603	9115	9627	10139
Objects	805	AD	0.25 mm	P	Pixel B	0	511	1023	1535	2047	2559	3071	3583	4095	4607	5119	5631	6143	6655	7167	7679	8191	8603	9115	9627	10139

Drop Size Distribution

$N(D)_{max} = 76.21$  1/mm<sup>3</sup>



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Date: June 14, 1996

Julian Day: 166

Event: 1

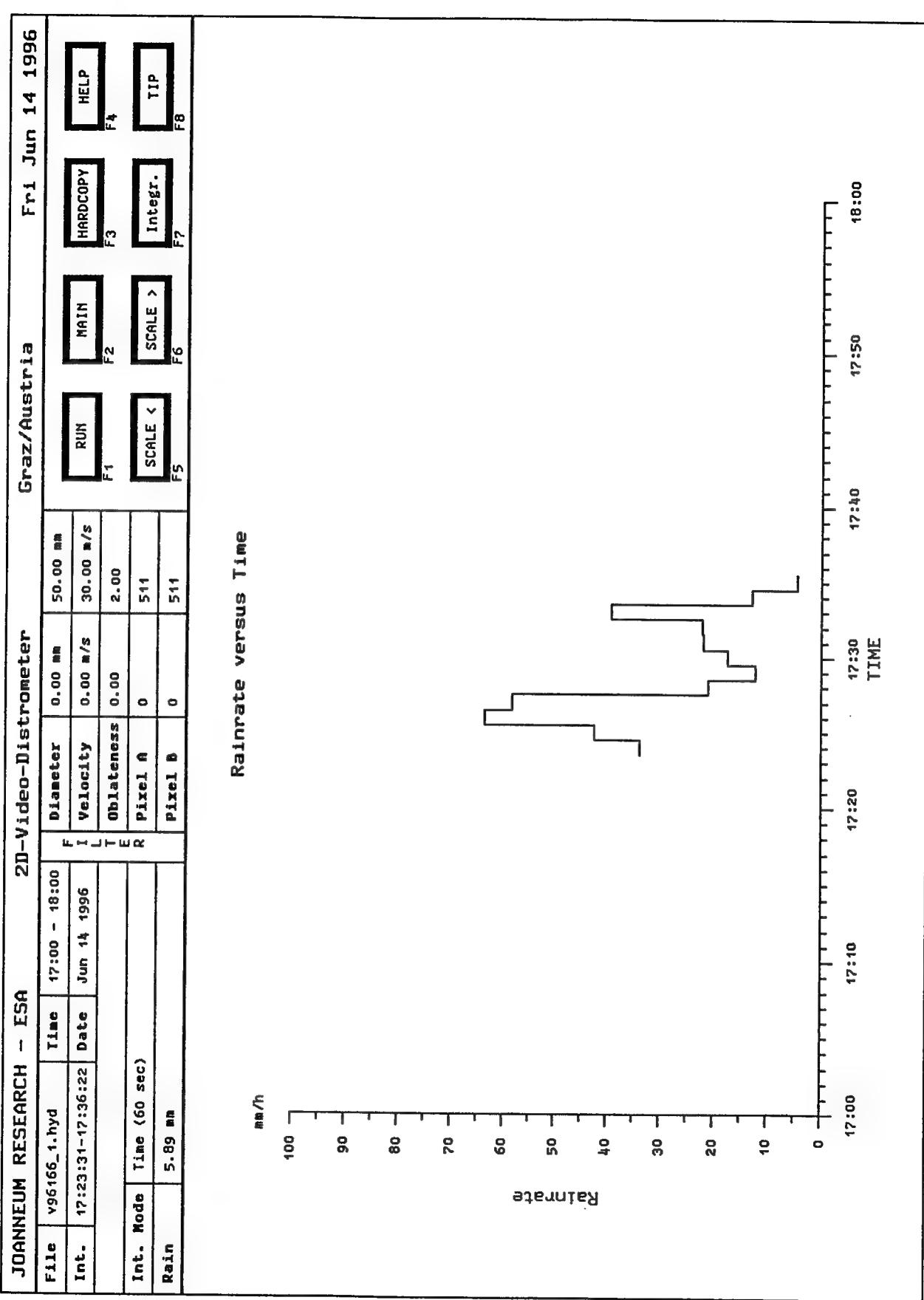
Time: 17:23-17:35

Average Rain Rate: 28.11mm\hr

Total Rainfall: 5.86mm

Location: Lat.- 40:34:47  
Lon.- 104:36:03

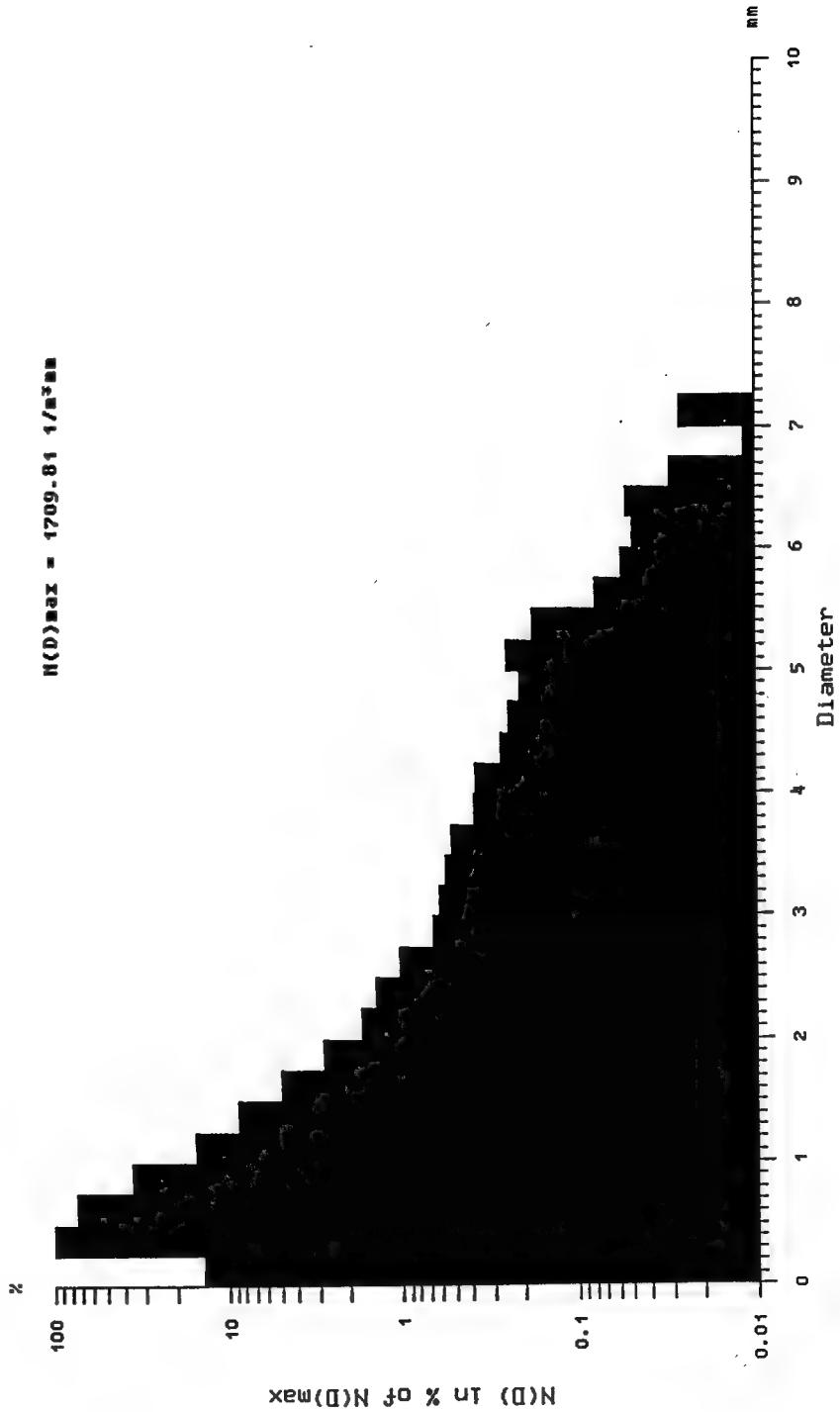
Contents: Little wind  
Large drops



JOANNEUM RESEARCH - ESA			2D-Video-Distrrometer			Graz/Austria			Fri Jun 14 1996		
File	v96166_1.hyd	Time	17:23 - 18:00	Diameter	0.00 mm	50.00 mm	Run	Main	HELP		
Int.	17:23:00-17:35:30	Date	Jun 14 1996	Velocity	0.00 m/s	30.00 m/s	F1	F2	F3		
Rain	5.86 mm			Oblateness	0.00	2.00					
Time Int	750.00 s	Rainrate	28.11 mm/h	Pixel A	0	511	AD <	Integr.	COMP		
Objects	13720	AD	0.25 mm	Pixel B	0	511	F5	F6	F7		

Drop Size Distribution

$N(D)_{\text{max}} = 1709.81 \text{ 1/mm}^3$



Date: June 15, 1996

Julian Day: 167

Event: I

Time: 14:15-14:40

Average Rain Rate: .56mm\hr

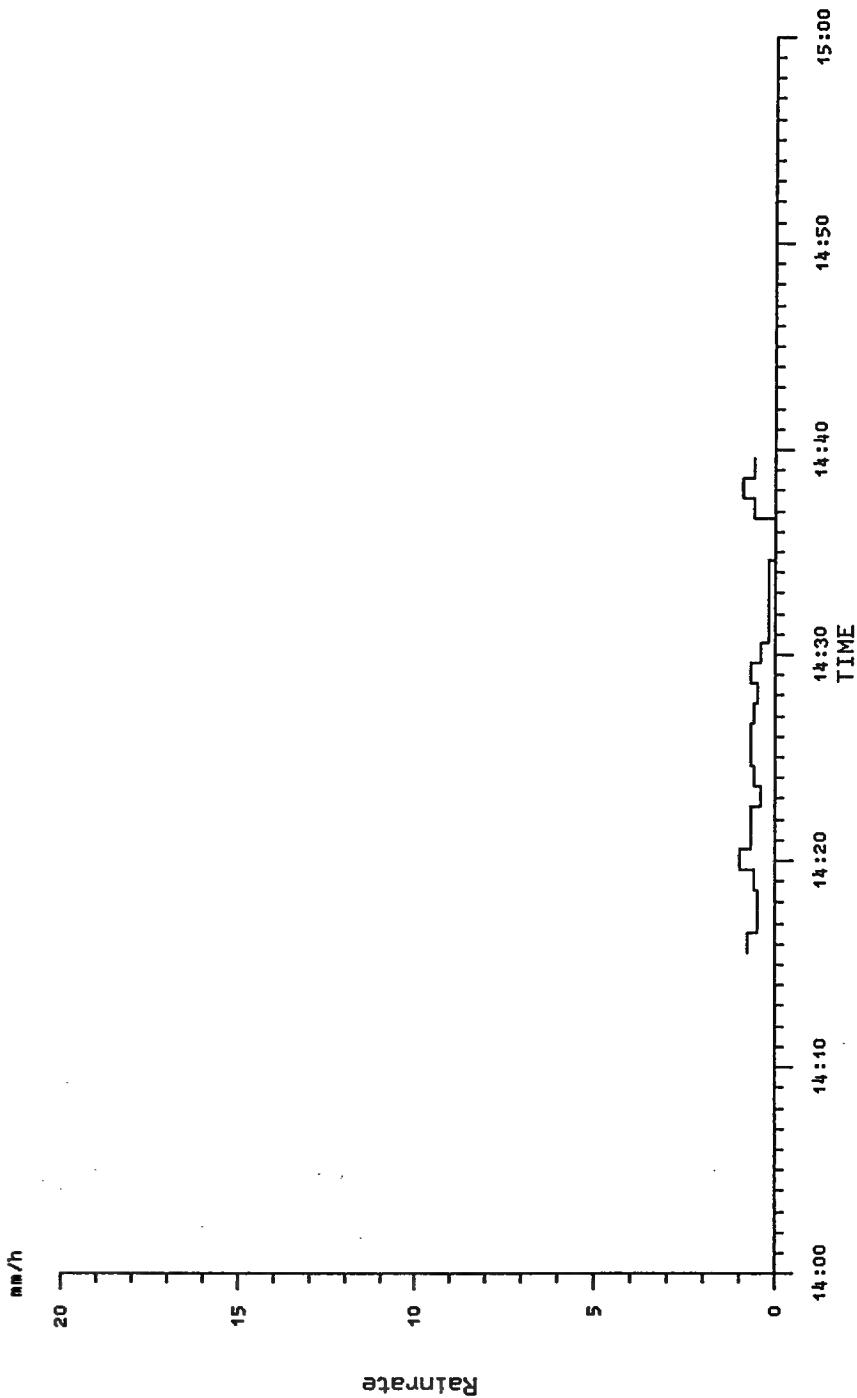
Total Rainfall: .23mm

Location: John Hubbert's driveway  
Lat.- 40:29:51  
Lon.- 105:03:35

Contents: Light rain  
Good distribution  
Van scans

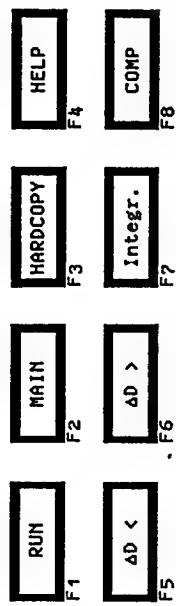
JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria					
File	v96167_1.nyd	Time	14:00 - 15:00	Diameter	0.00 mm	50.00 mm	Run	Main	HARDCOPY	HELP							Sat Jun 15 1996
Int.	14:15:36-14:40:02	Date	Jun 15 1996	Velocity	0.00 m/s	30.00 m/s	F1	F2	F3	F4							
				Oblateness	0.00	2.00											
Int.	Mode	Time (60 sec)		Pixel A	0	511	SCALE <	SCALE >	Integr.	TIP							
Rain				Pixel B	0	511	F5	F6	F7	F8							

Rainrate versus Time



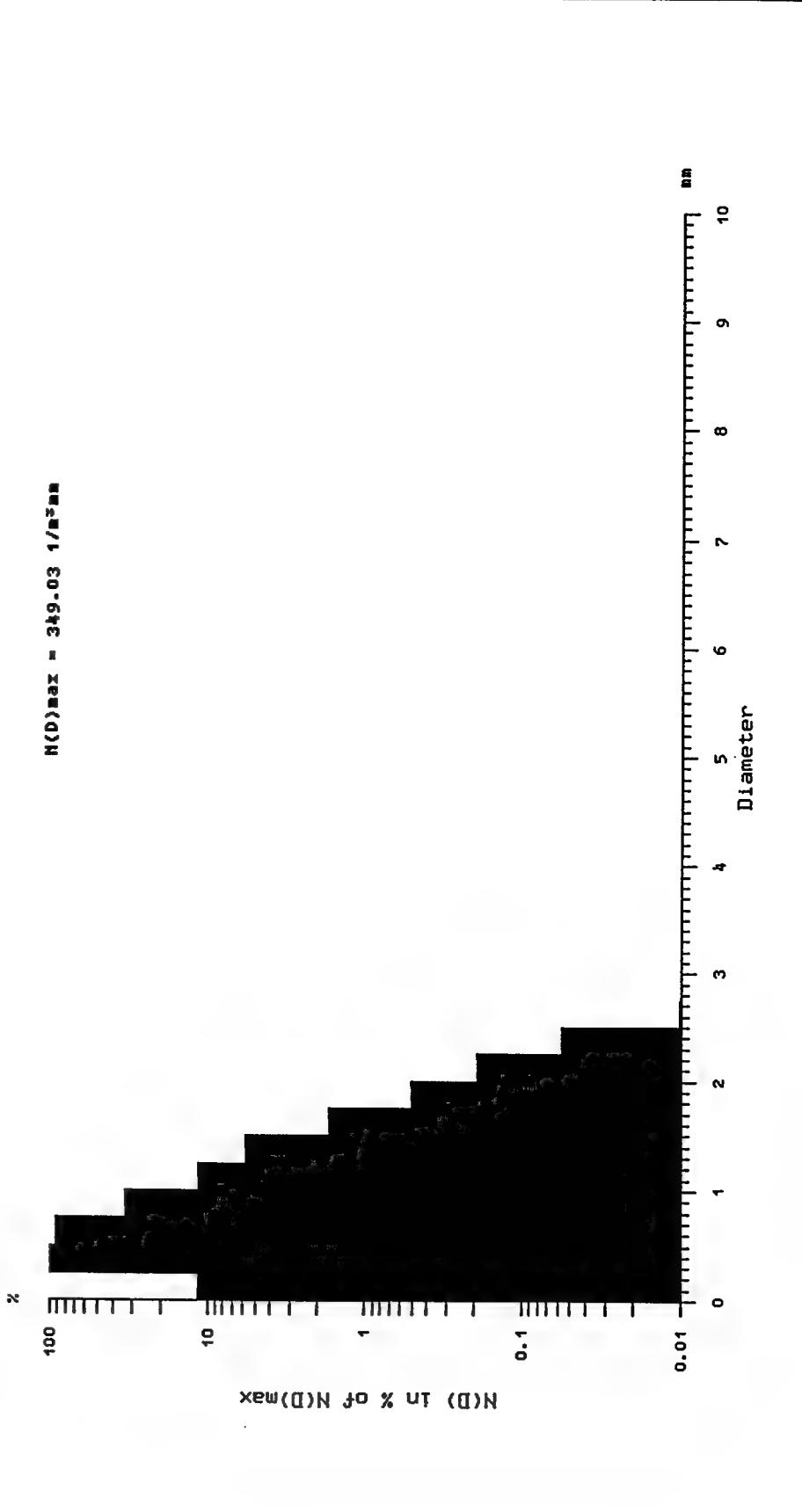
JOANNEUM RESEARCH - ESA 2D-Video-Distrometer Graz/Austria Sat Jun 15 1996

File	v96167_1.lyd	Time	14:15 - 15:00	F	Diameter	0.00 mm	50.00 mm
Int.	14:15:00-14:40:00	Date	Jun 15 1996	I	Velocity	0.00 m/s	30.00 m/s
Rain	0.23 mm			L	Oblateness	0.00	2.00
Time Int	1500.00 s	Rainrate	0.56 mm/h	R	Pixel A	0	511
Objects	6245	AD	0.25 mm	R	Pixel B	0	511



Drop Size Distribution

$N(D)_{max} = 349.03 1/mm^3$



---

Date: June 20, 1996

Julian Day: 172

Event: 1

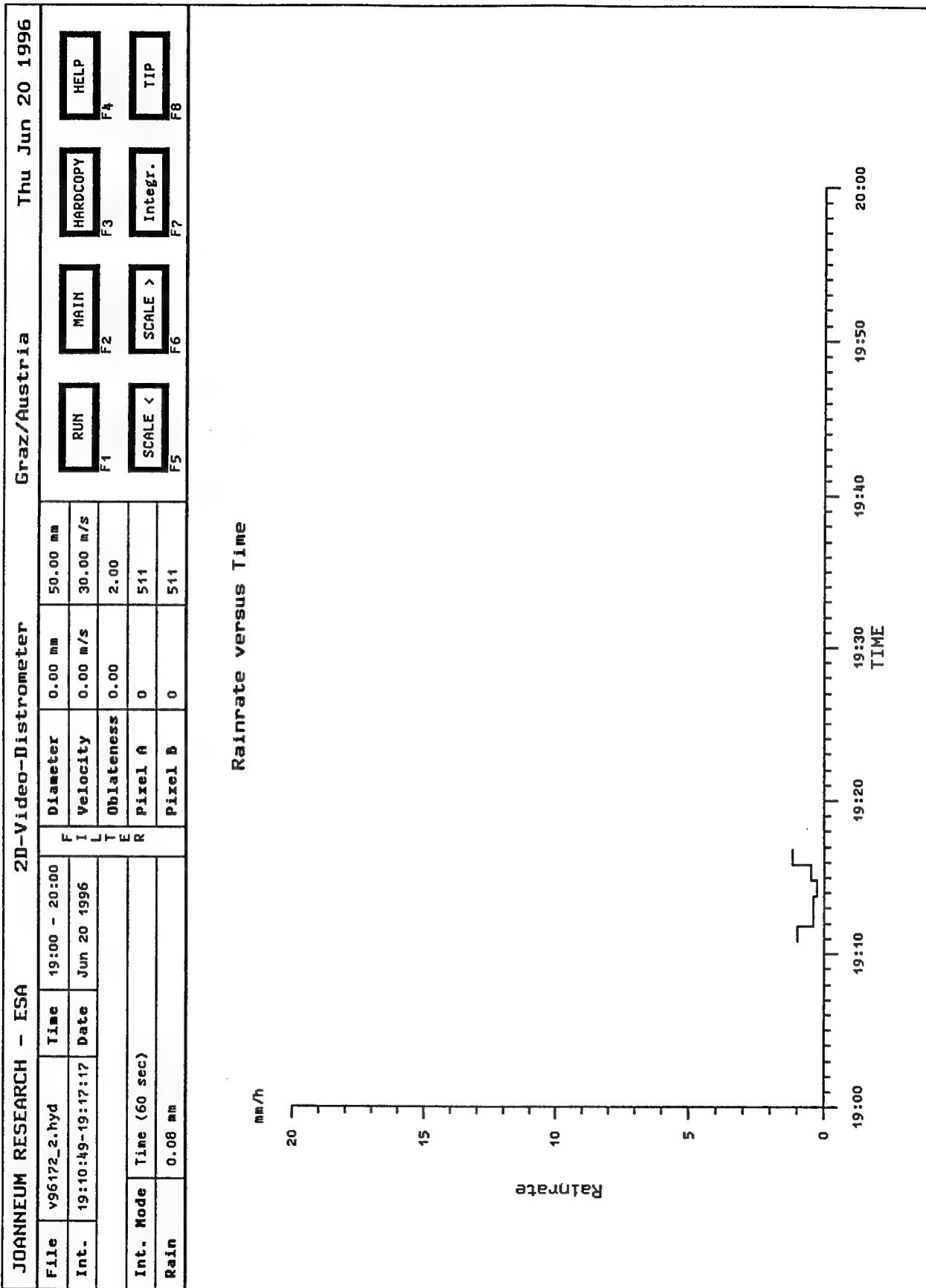
Time: 19:10-19:17

Average Rain Rate: .62mm\hr

Total Rainfall: .07mm

Location: County road 49 & 22  
Lat.- 40:10:29  
Lon.-104:36:10

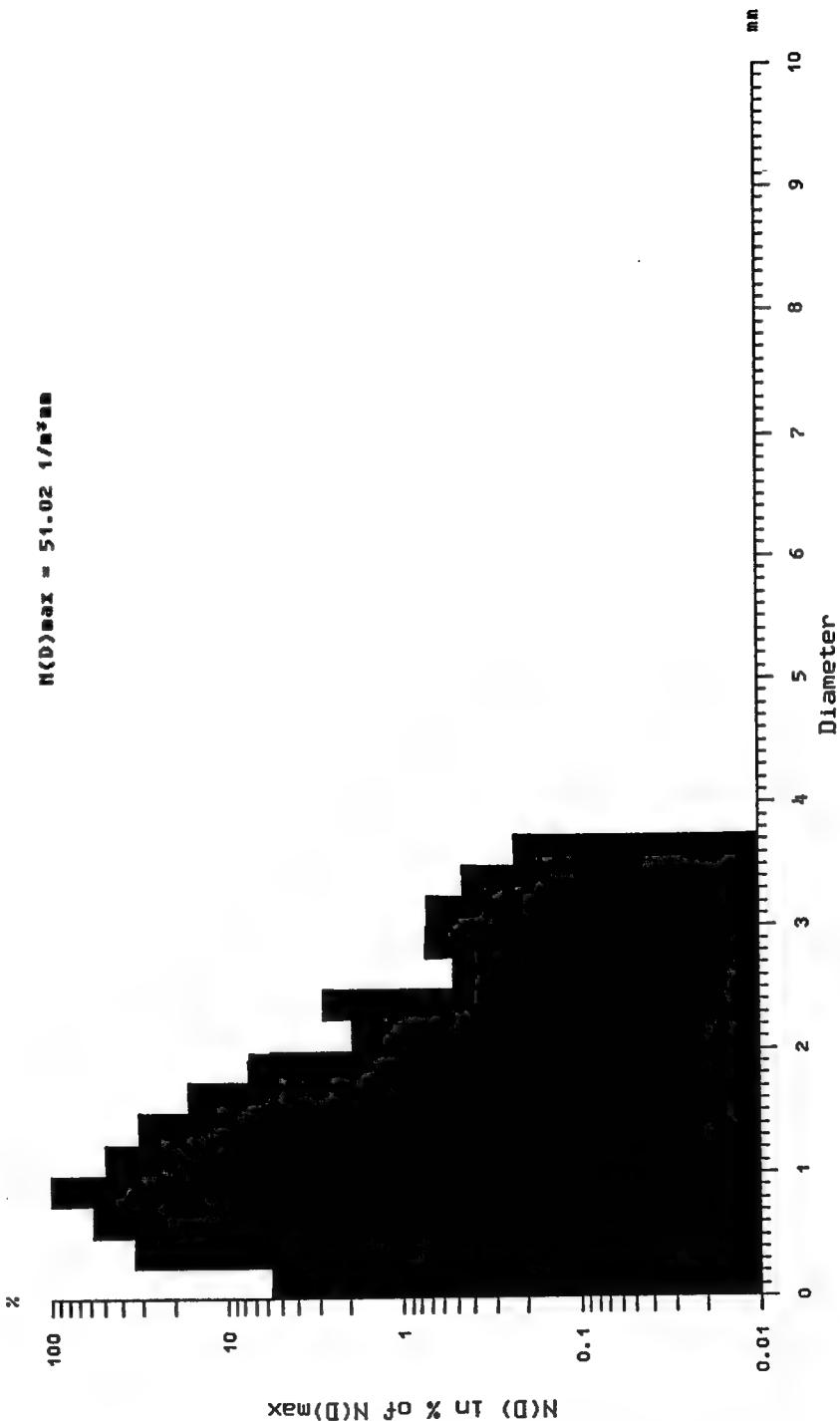
Contents: Light rain



JOANNEUM RESEARCH - ESA						2D-Video-Distrrometer						Graz/Austria						Thu Jun 20 1996							
File	v96172_2.hyd	Time	19:10 - 20:00	Diameter	0.00 mm	50.00 mm	RUN	MAIN	HARDCOPY	HELP	F1	F2	F3	F4	F5	F6	F7	F8	AD <	AD >	Integr.	F5	F6	F7	F8
Int.	19:10:00-19:17:00	Date	Jün 20 1996	F	I	Velocity	0.00 m/s	30.00 m/s	30.00 m/s	30.00 m/s	F1	F2	F3	F4	F5	F6	F7	F8	AD <	AD >	Integr.	F5	F6	F7	F8
Rain	0.07 mm			L	T	Oblateness	0.00	2.00																	
Time Int	420.00 s	Rainrate	0.62 mm/h	E	R	Pixel A	0	511																	
Objects	518	AD	0.25 mm	R	Pixel B	0	511																		

### Drop Size Distribution

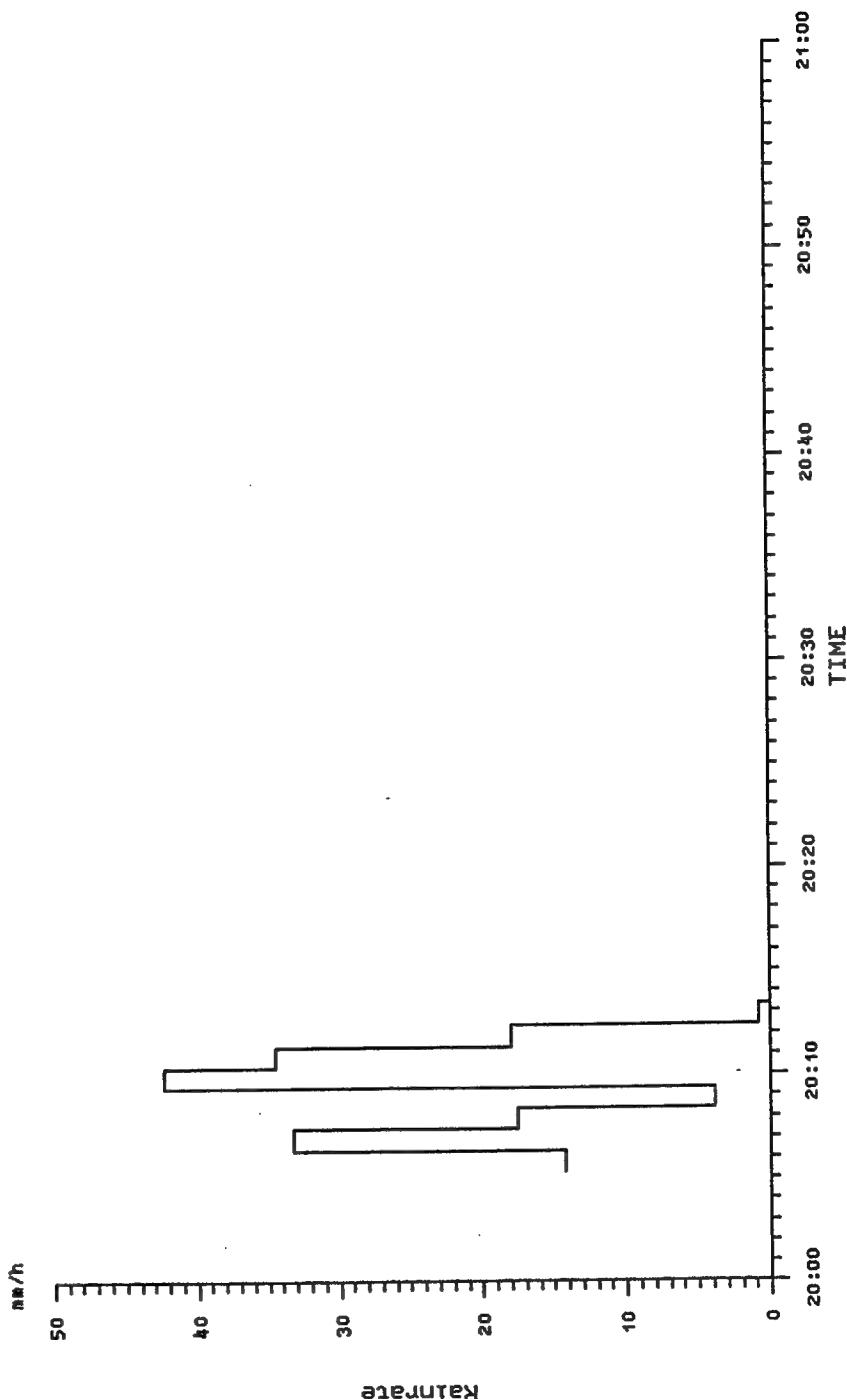
$$N(D)_{\text{max}} = 51.02 \text{ 1/mm}^3$$



Date: June 20, 1996  
Julian Day: 172  
Event: 2  
Time: 20:05-20:14  
Average Rain Rate: 18.36mm\hr  
Total Rainfall: 2.75mm  
Location: County road 74 & highway 392  
Lat.- 40:31:22  
Lon.-104:24:50  
Contents: Heavy rain  
No hail

JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria				Thu Jun 20 1996				
File	v96172_3.hyd	Time	20:00 - 21:00	F	Diameter	0.00 mm	50.00 mm	F	MAIN	HARDCOPY	HELP	F	RUN	MAIN	HARDCOPY	HELP
Int.	20:05:21-20:14:26	Date	Jun 20 1996	I	Velocity	0.00 m/s	30.00 m/s	I	F2	F3	F4	F1	Velocity	0.00 m/s	30.00 m/s	Velocity
Int.	Mode	Time (60 sec)		T	Oblateness	0.00	2.00	T								
Rain				R	Pixel A	0	511	R								
					Pixel B	0	511	F5				F6	Pixel A	Pixel B	Pixel A	Pixel B
								F7				F8				

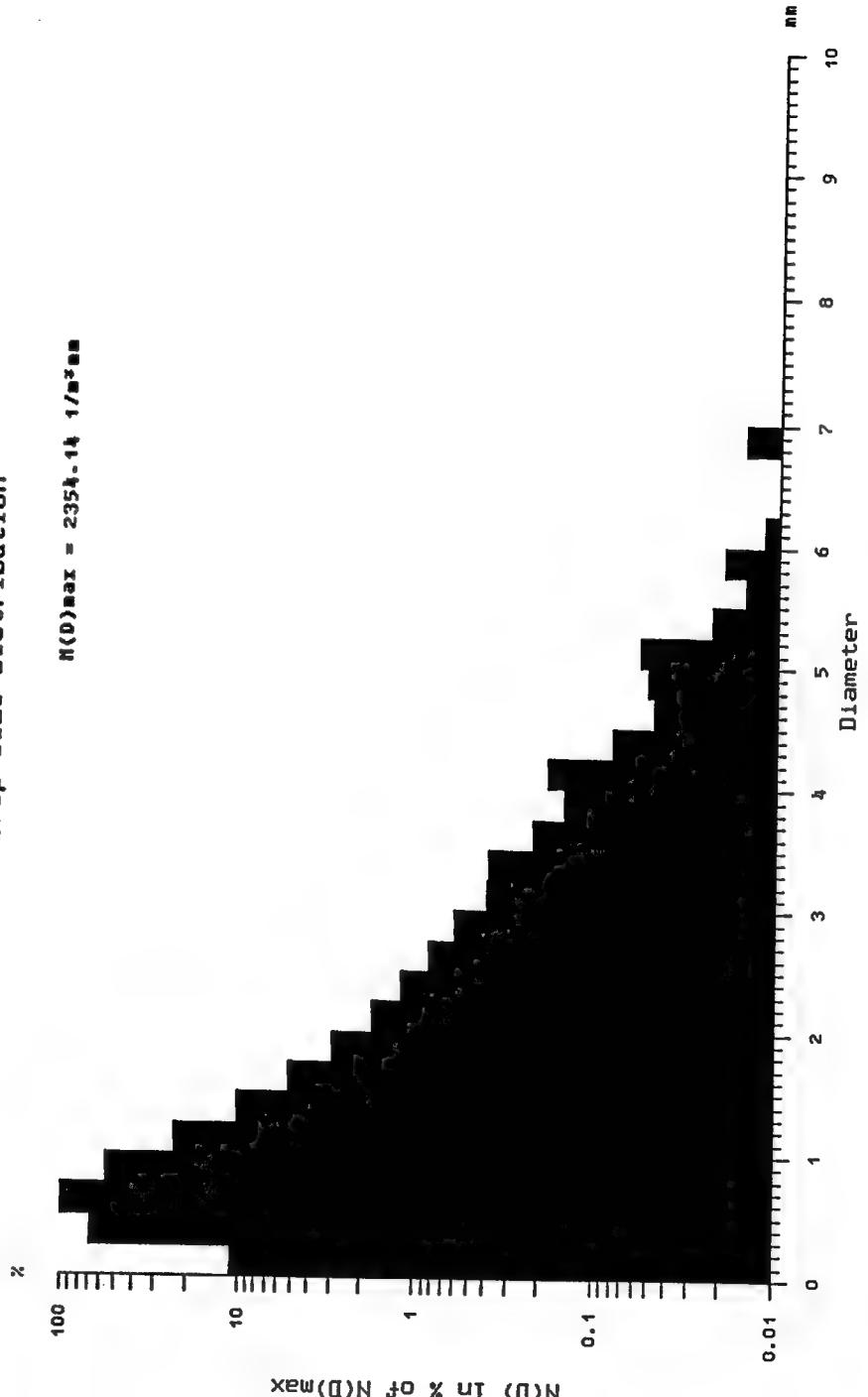
Rainrate versus Time



JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria						Thu Jun 20 1996					
File	v96172_3.hyd		Time	20:05 - 21:00		Diameter	0.00 mm		50.00 mm		Run	MAIN		HARDCOPY		HELP							
Int.	20:05:00-20:14:00		Date	Jun 20 1996		F	I	Velocity	0.00 m/s		30.00 m/s	F1	F2	F3	F4	F5	F6	F7	F8				
Rain	2.75 mm					L	T	Oblateness	0.00		2.00												
Time	Int	540.00 s	Rainrate	18.36 mm/h		R	Pixel A		0		511		AD <		AD >		Integr.		COMP				
Objects	14637	AD		0.25 mm			Pixel B		0		511		FS		F6		F7		F8				

Drop Size Distribution

$N(D)_{\text{max}} = 2354.14 \text{ 1/mm}^3$



Date: June 20, 1996

Julian Day: 172

Event: 3

Time: 20:34-20:44

Average Rain Rate: 62.63mm\hr

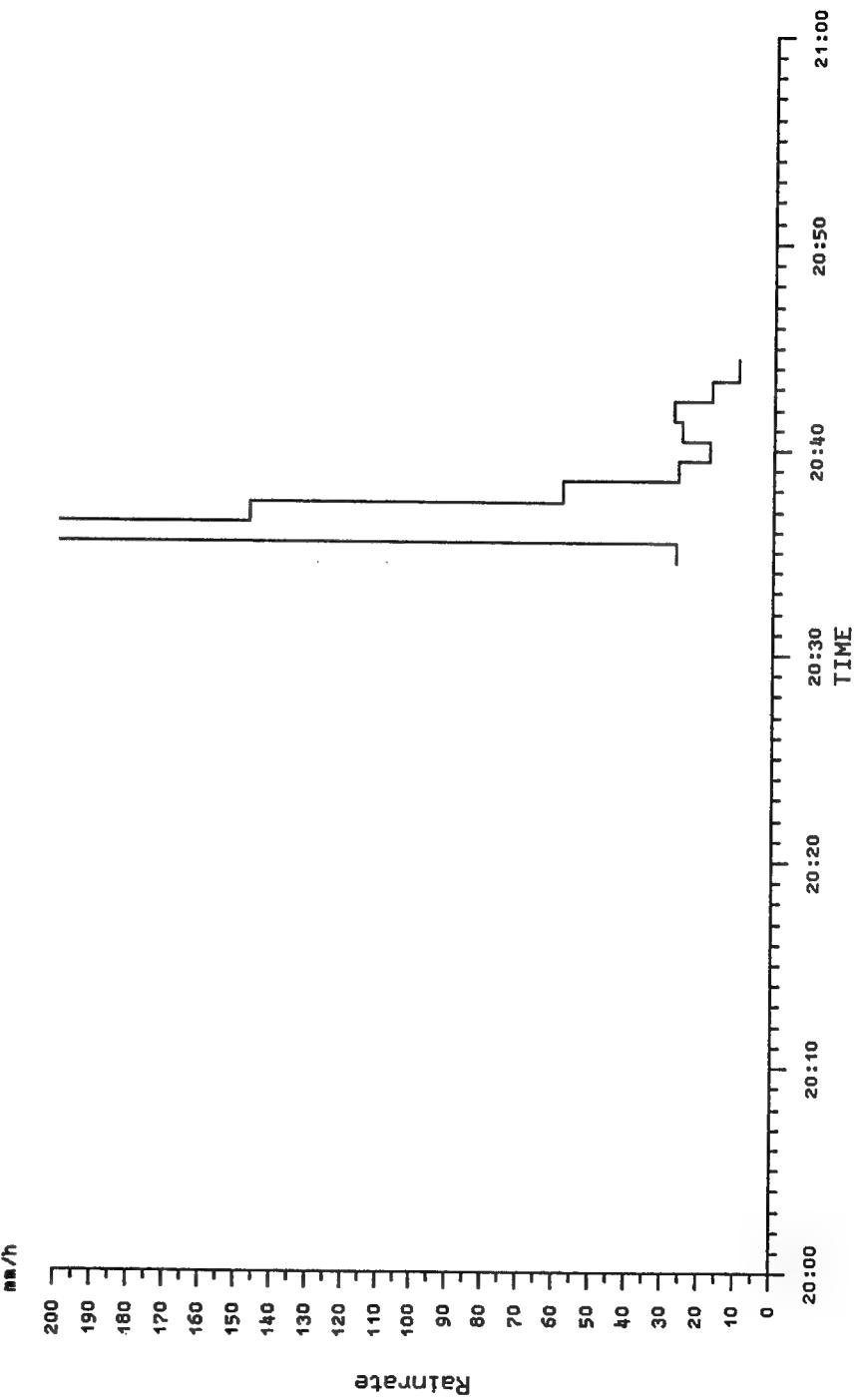
Total Rainfall: 11.36mm

Location: highway 14 & 392  
Lat.- 40:31:22  
Lon.-104:24:50

Contents: Heavy rain and hail  
Pea-sized and marble-sized hail  
Zero visibility  
Note: File v96172\_4.hyd is only two minutes long and was not included  
Note: File v96172\_6.hyd is very short and small also and was not included..

JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria					
File	v96172_5.lyd	Time	20:00 - 21:00	F	Diameter	0.00 mm	50.00 mm	F	MAIN	F2	MAIN	F3	HARDCOPY	F4	HELP		
Int.	20134:24-20:44:53	Date	Jun 20 1996	I	Velocity	0.00 m/s	30.00 m/s	I	RUN	F1	RUN	F1	SCALE >	F7	TIP		
Int.	Mode	Time (60 sec)		E	Oblateness	0.00	2.00										
Rain				R	Pixel A	0	511										
				P	Pixel B	0	511										
								F5									
								F6									
								F8									

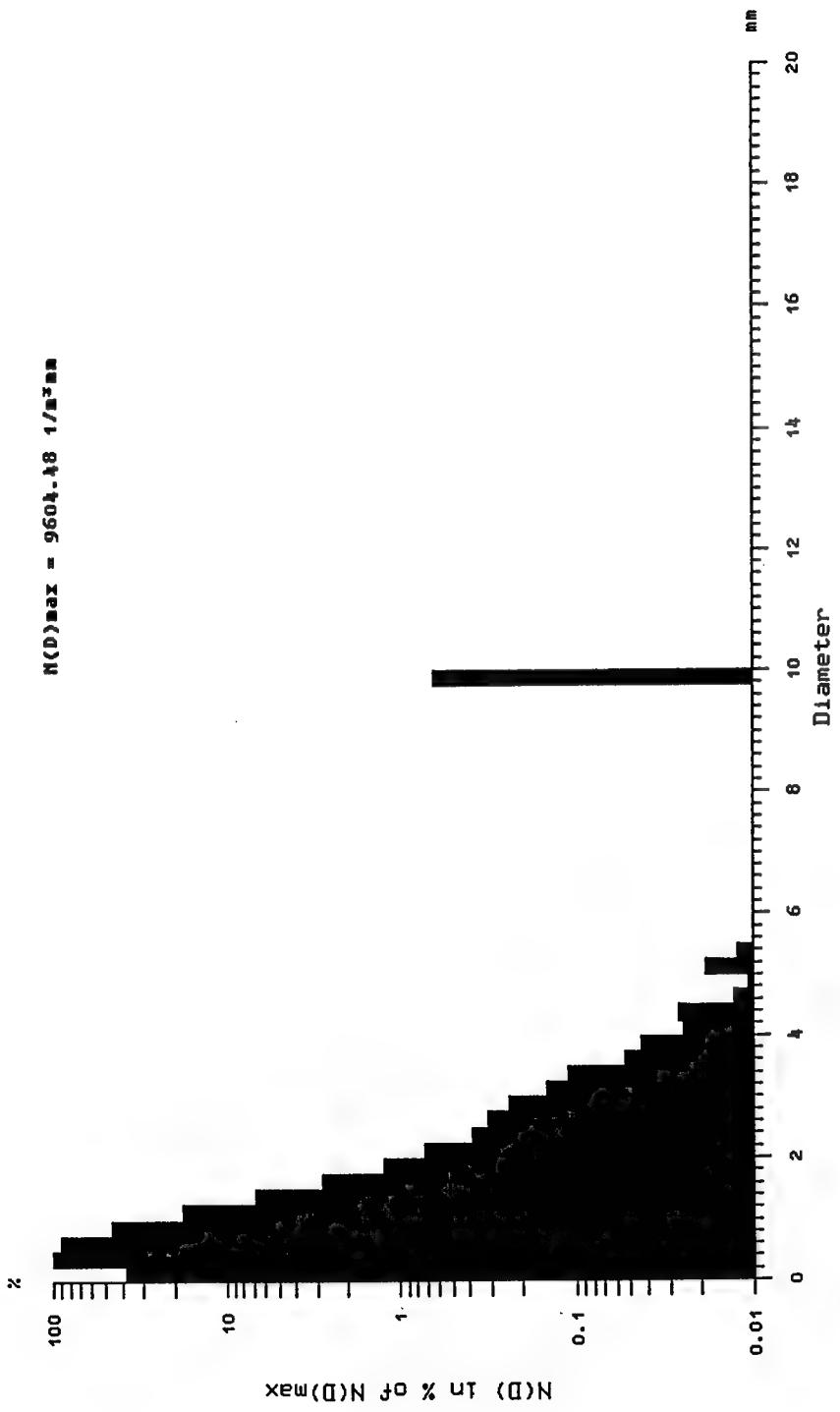
Rainrate versus Time



JOANNEUM RESEARCH - ESA						2D-Video-Distrrometer						Graz/Austria						Thu Jun 20 1996									
File	vr961725.hyd	Time	20:34 - 21:00	Diameter	0.00 mm	50.00 mm	50.00 mm	MAIN	HARDCOPY	HELP	F1	RUN	F2	F3	F4	MAIN	HARDCOPY	HELP	F1	F2	F3	F4	F5	F6	F7	F8	
Int.	20:34:00-20:44:53	Date	Jun 20 1996	Velocity	0.00 m/s	30.00 m/s	30.00 m/s																				
Rain	11.36 mm			Oblateness	0.00	2.00																					
Time Int	653.00 s	Rainrate	62.63 mm/h	Pixel A	0	511																					
Objects	59629	AD	0.25 mm	Pixel B	0	511																					

### Drop Size Distribution

$N(D)_{\text{max}} = 9604.48 \text{ 1/mm}^3$



Date: June 21, 1996

Julian Day: 173

Event: 1

Time: 15:12-15:24

Average Rain Rate: 5.75mm\hr

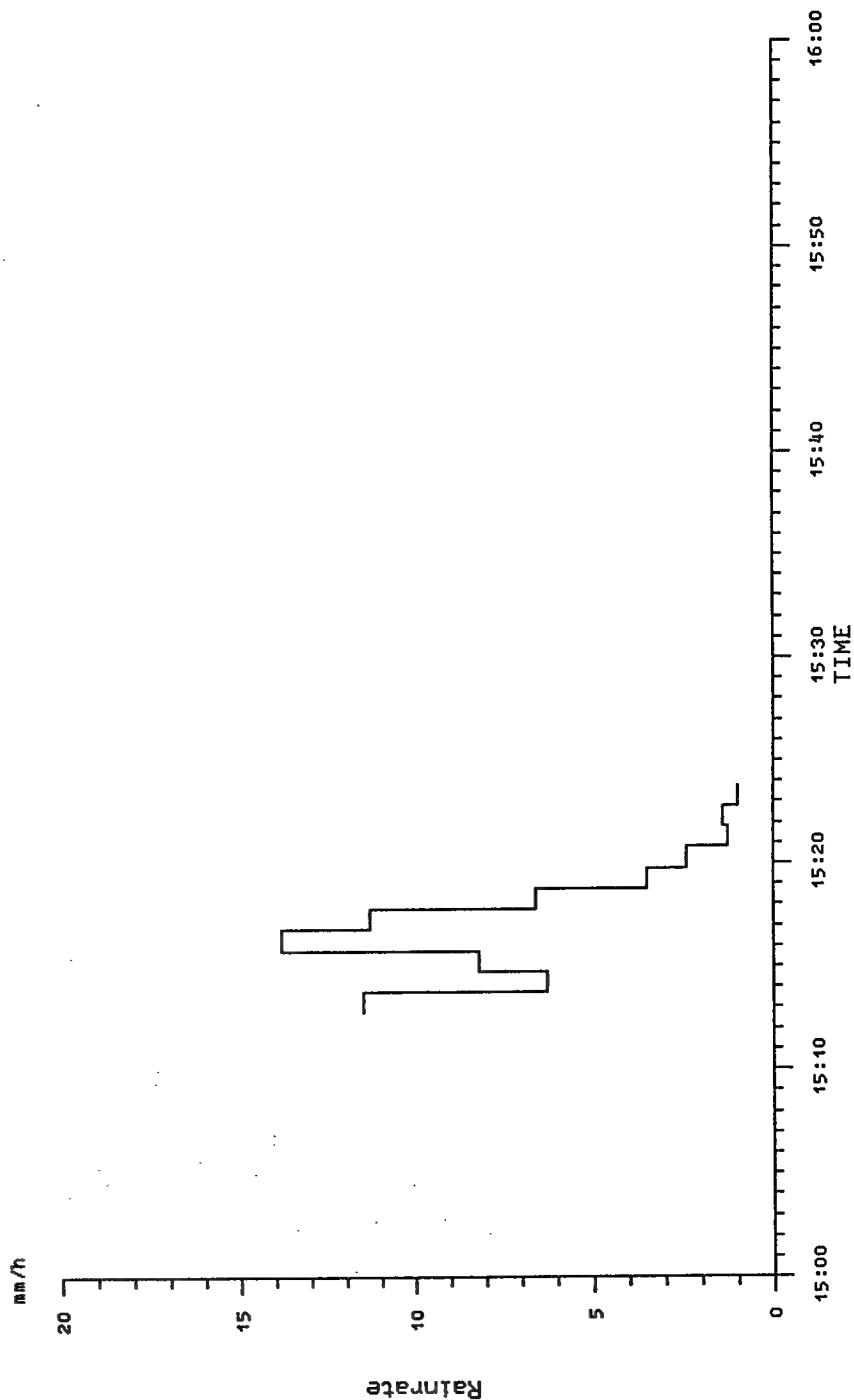
Total Rainfall: 1.17mm

Location: County road 43 & highway 14  
Lat.- 40:34:39  
Lon.-104:39:30

Contents: Moderate rain

JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria						Fri Jun 21 1996							
File	v96173_2.hyd	Time	15:00	-	16:00	F	Diameter	0.00 mm	50.00 mm			RUN	MAIN												
Int.	15:12:47-15:24:38	Date	Jun 21	1996	I	Velocity	0.00 m/s	30.00 m/s																	
					L	Oblateness	0.00	2.00																	
					E																				
					R	Pixel A	0	511																	
						Pixel B	0	511																	
Rain	1.17 mm																								

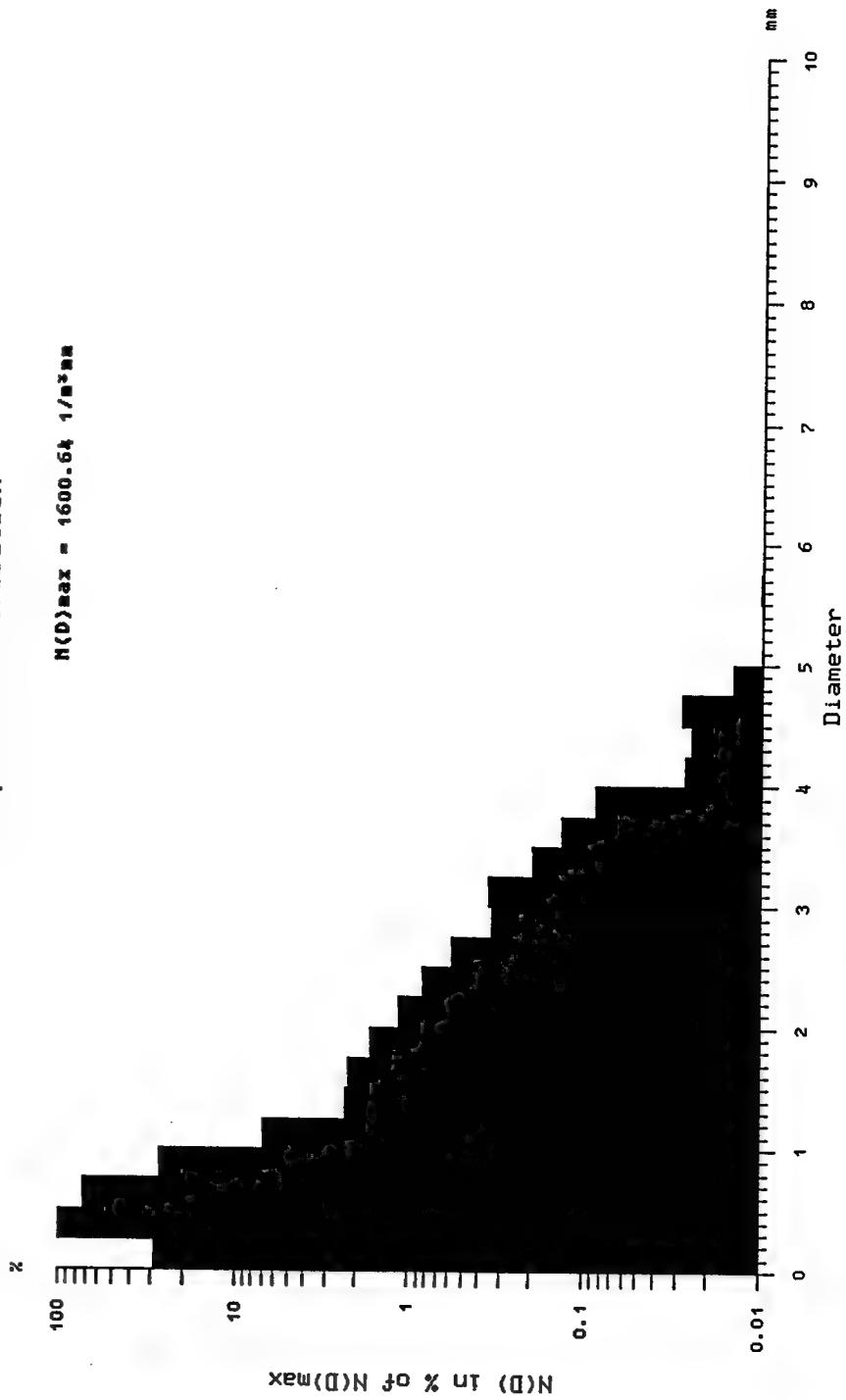
Rainrate versus Time



JOANNEUM RESEARCH - ESA 2D-Video-Distrrometer Graz/Austria Fri Jun 21 1996									
File	v96173_2.hyd	Time	15:12 - 15:30	Diameter	0.00 mm	50.00 mm			
Int.	15:12:00-15:21:10	Date	Jun 21 1996	Velocity	0.00 m/s	30.00 m/s			
Rain	1.17 mm			Oblateness	0.00	2.00			
Time Int	730.00 s	Rainrate	5.75 mm/h	Pixel A	0	511			
Objects	9562	AD	0.25 mm	Pixel B	0	511			
				AD <	F5	AD >	F6	Integr.	F7
								COMP	F8

Drop Size Distribution

$N(D)_{max} = 1600.64 1/mm^3$



---

Date: June 21, 1996

Julian Day: 173

Event: 2

Time: 15:41-15:50

Average Rain Rate: 8.22mm\hr

Total Rainfall: 1.3mm

Location: County road 43 & 76  
Lat.- 40:31:22  
Lon.-104:34:32

Contents: Light rain

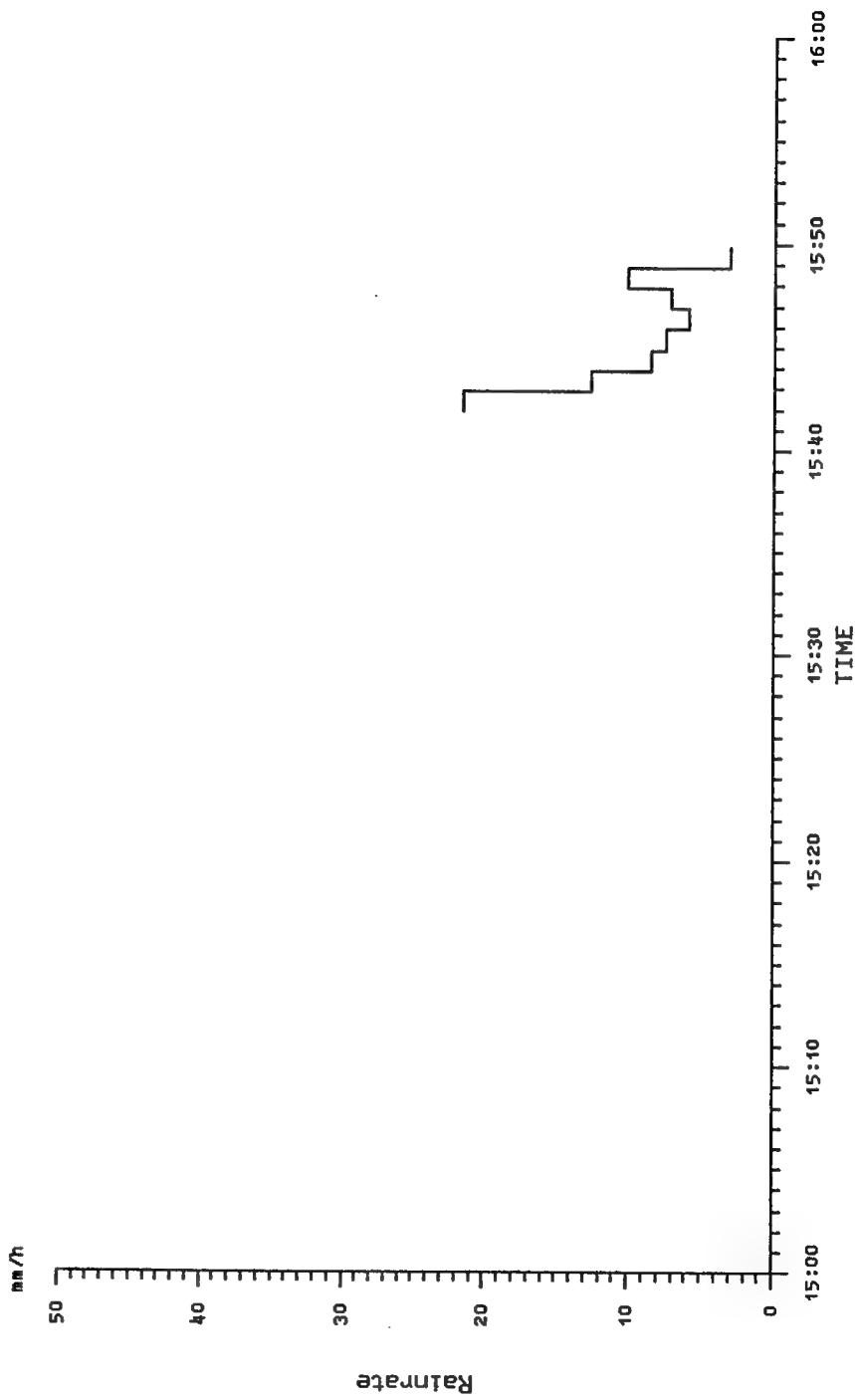
## JOANNEUM RESEARCH - ESA

## 2D-Video-Distrometer

Graz/Austria Fri Jun 21 1996

File	v96173_3.lyd	Time	15:40 - 16:00	Diameter	0.00 mm	50.00 mm	RUN	MAIN	HELP
Int.	15:41:52-15:50:44	Date	Jun 21 1996	F Velocity	0.00 m/s	30.00 m/s	F1	MAIN	HARDCOPY
				L Oblateness	0.00	2.00	F2	HARDCOPY	F3
				E			F3		F4
Int. Mode	Time (60 sec)	R Pixel A	0	511			F4	Integr.	TIP
Rain	1.31 mm	Pixel B	0	511			F5	SCALE >	F7
							F6	SCALE <	F8

Rainrate versus Time

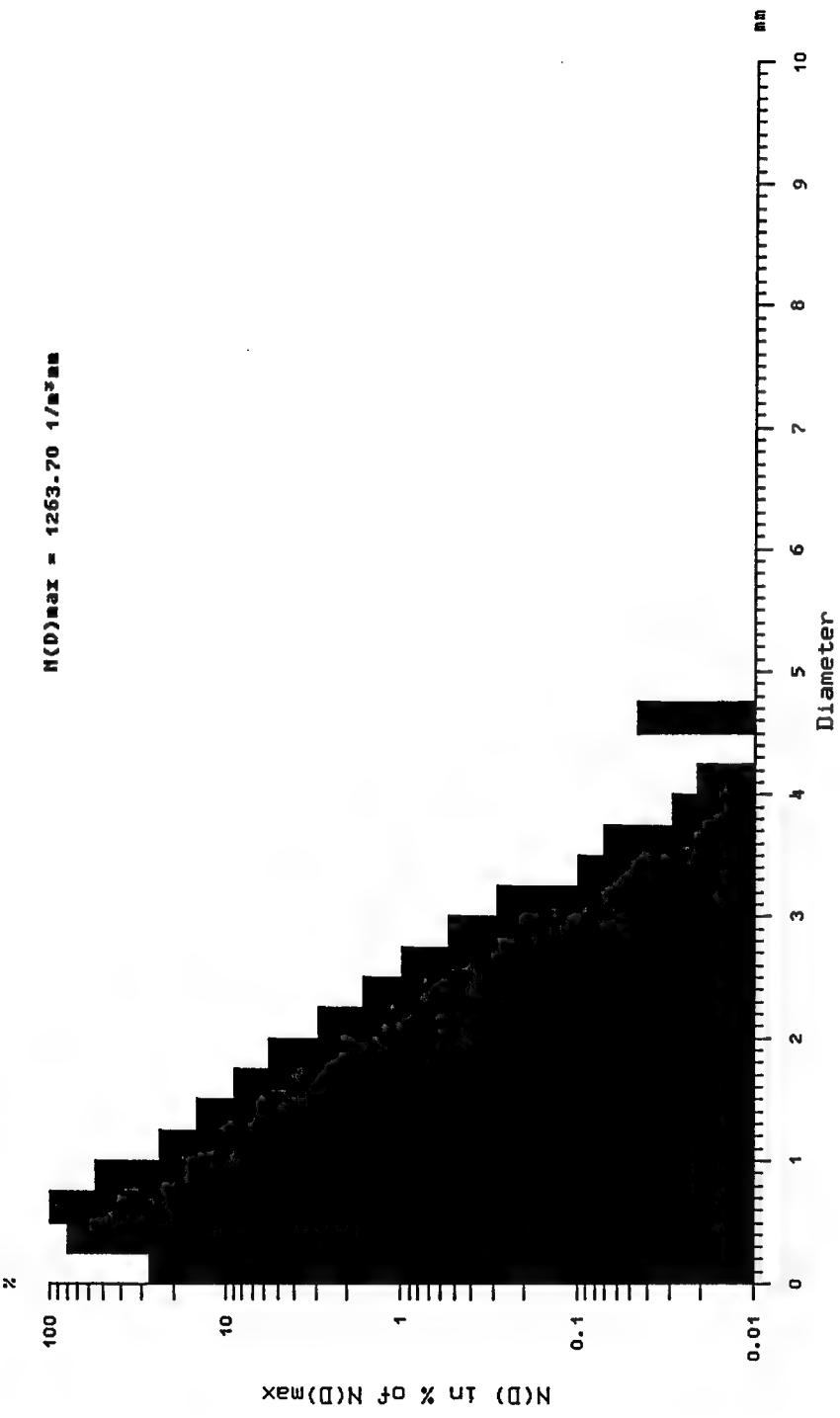


JOANNEUM RESEARCH - ESA			2D-Video-Distrrometer			Graz/Austria			Fri Jun 21 1996		
File	v96173_3.hyd	Time	15:41 - 16:00	Diameter	0.00 mm	50.00 mm					
Int.	15:41:00-15:50:30	Date	Jun 21 1996	F							
Rain	1.30 mm			I	Velocity	0.00 m/s	30.00 m/s				
Time Int	570.00 s	Rainrate	8.22 mm/h	L							
Objects	9310	AD	0.25 mm	E	Oblateness	0.00	2.00				
				R	Pixel A	0	511				
				R	Pixel B	0	511				

<input type="button" value="HELP"/>	<input type="button" value="HARDCOPY"/>
<input type="button" value="MAIN"/>	<input type="button" value="RUN"/>
<input type="button" value="F2"/>	<input type="button" value="F1"/>
<input type="button" value="F3"/>	<input type="button" value="F4"/>
<input type="button" value="AD &gt;"/>	<input type="button" value="AD &lt;"/>
<input type="button" value="Integr."/>	<input type="button" value="COMP"/>
<input type="button" value="F7"/>	<input type="button" value="F6"/>
<input type="button" value="F8"/>	<input type="button" value="F5"/>

### Drop Size Distribution

$N(D)_{\text{max}} = 1263.70$  1/mm<sup>3</sup>



Date: June 21, 1996

Julian Day: 173

Event: 3

Time: 16:18-16:27

Average Rain Rate: 21.91mm\hr

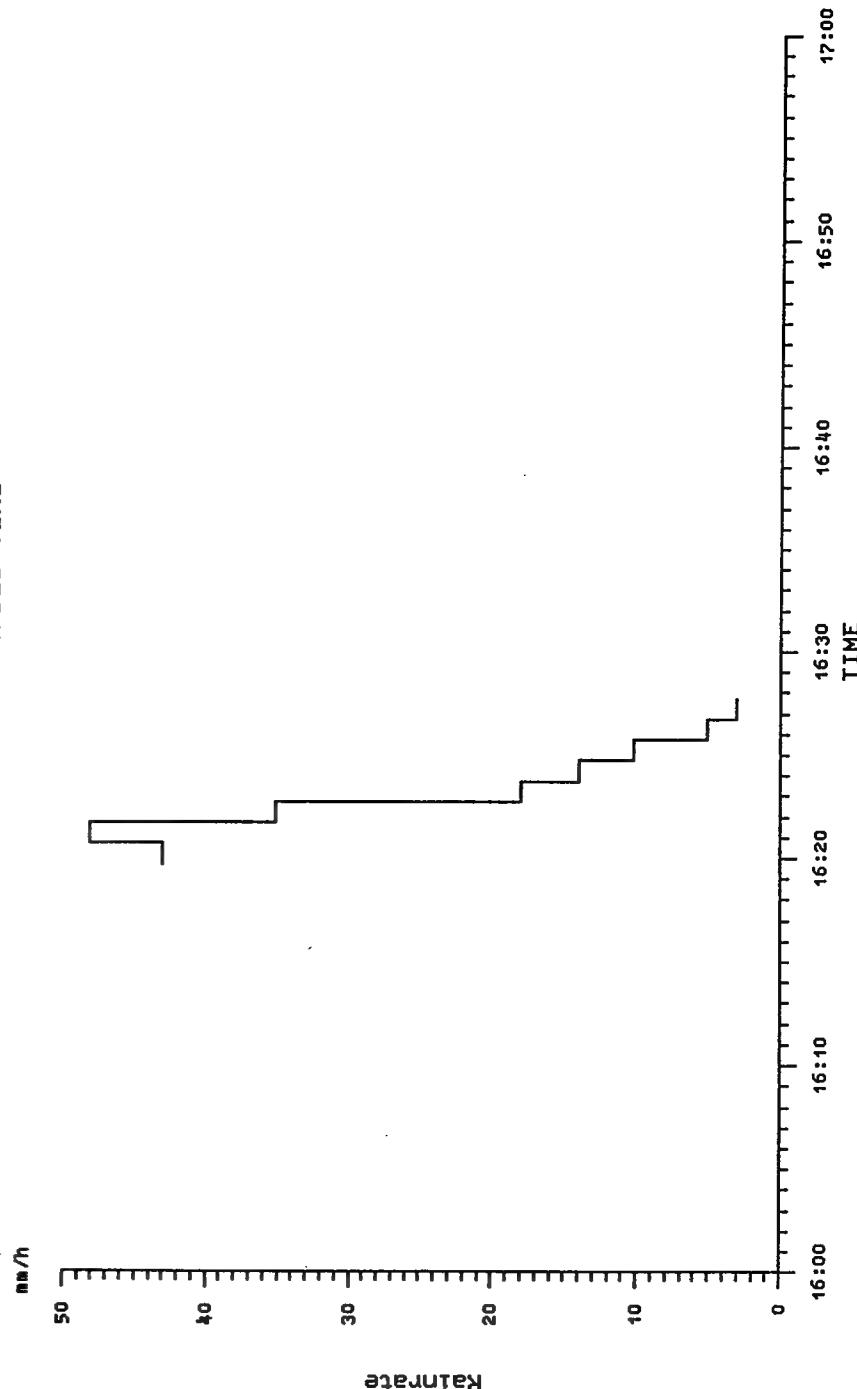
Total Rainfall: 2.92mm

Location: Lat.- 40:18:37  
Lon.-104:22:39

Contents: Moderate to heavy rain

JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria				Fri Jun 21 1996			
File	v96173_4.hyd	Time	16:00 - 17:00	Diameter	0.00 mm	50.00 mm		MAIN	HARDCOPY	HELP					
Int.	16:19:43-16:27:50	Date	Jun 21 1996	F	0.00 m/s	30.00 m/s		RUN							
				I	Velocity			F1	F2	F3	F4				
				L											
				T	Oblateness	0.00	2.00								
				E											
				R	Pixel A	0	511								
				S	Pixel B	0	511								
Rain	2.96 mm														

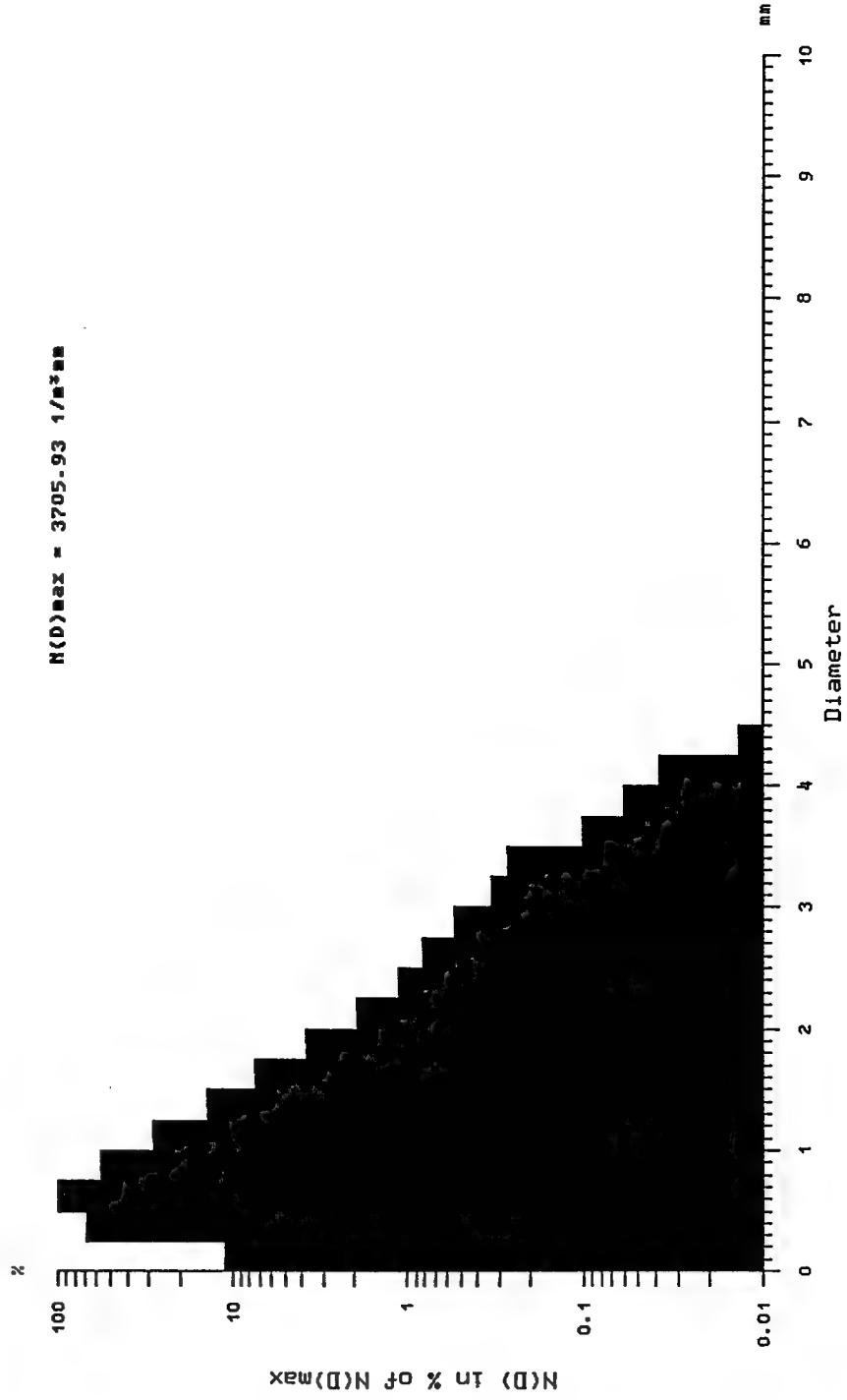
Rainrate versus Time



JOANNEUM RESEARCH - ESA										2D-Video-Distrometer		Graz/Austria		Fri Jun 21 1996						
File	V96173_4.hyd			Time	16:19 - 16:30			Diameter	0.00 mm			50.00 mm			RUN		MAIN			
Int.	16:19:00-16:27:00			Date	Jun 21 1996			I	Velocity	0.00 m/s			30.00 m/s			F1		F2		
Rain	2.92 mm							L	Oblateness	0.00			2.00							
Time	Int	480.00	s	Rainrate	21.91 mm/h			R	Pixel A	0			511			$\Delta D <$	AD >		Integr.	
Objects	21162			AD	0.25 mm			P	Pixel B	0			511			F5	F6		F7	

Drop Size Distribution

$N(D)_{\text{max}} = 3705.93$  1/mm<sup>3</sup>



Date: June 24, 1996

Julian Day: 176

Event: 1

Time: 17:03-17:12

Average Rain Rate: .58mm\hr

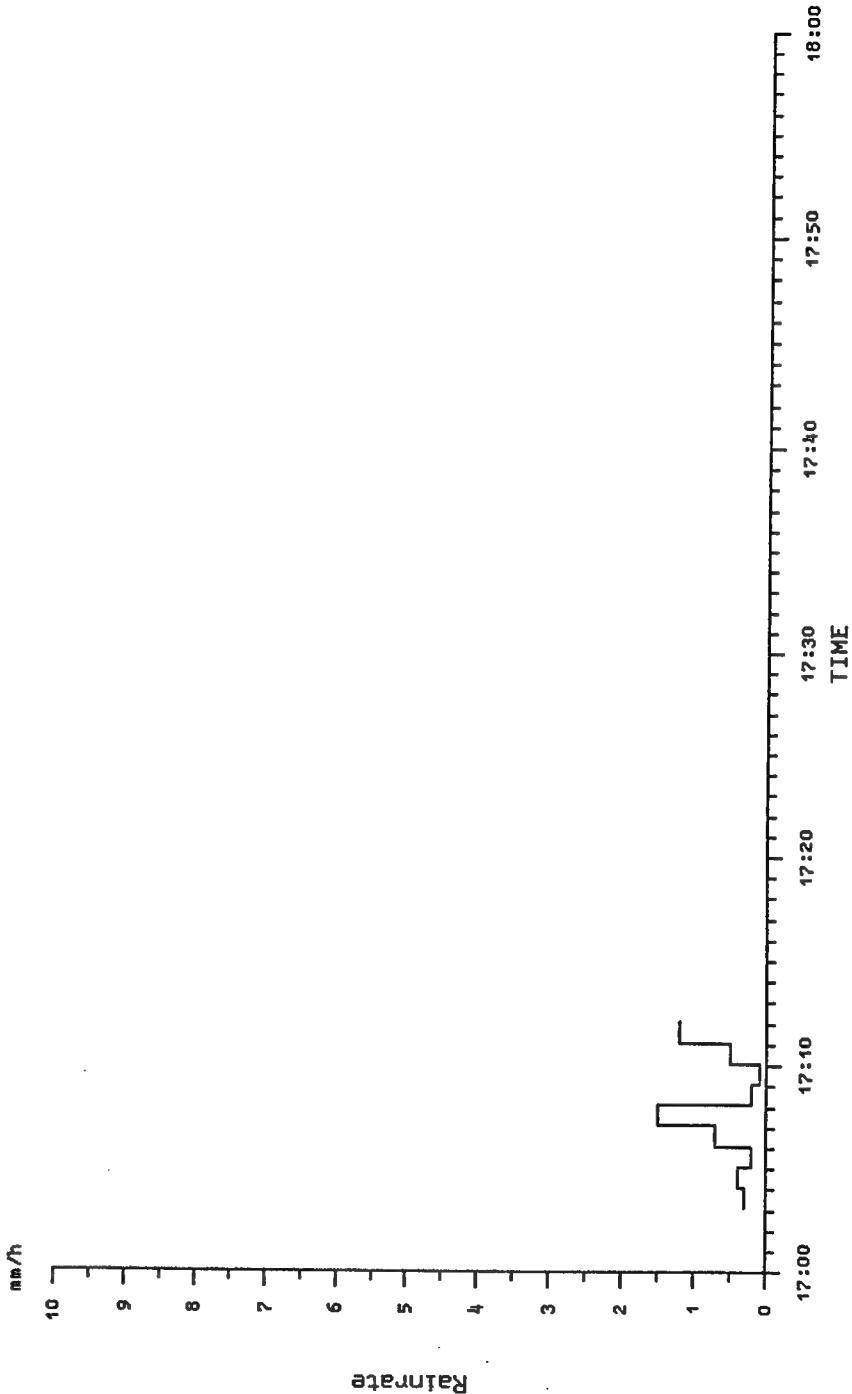
Total Rainfall: .09mm

Location: Lat.- 40:17:39  
Lon.-104:18:33

Contents: Almost no rain

JOANNEUM RESEARCH - ESR						2D-Video-Distrometer						Graz/Austria						Mon Jun 24 1996					
File	v96126_2.hyd	Time	17:03 - 18:00	F	Diameter	0.00 mm	50.00 mm	RUN	MAIN	HARDCOPY	HELP												
Int.	17:03:06-17:12:41	Date	Jun 24 1996	I	Velocity	0.00 m/s	30.00 m/s	F1	F2	F3	F4												
				L	Oblateness	0.00	2.00																
Int. Mode	Time (60 sec)	R	Pixel A	0	511			SCALE <	SCALE >	Integr.	TIP												
Rain	0.09 mm		Pixel B	0	511			F5	F6	F7	F8												

Rainrate versus Time

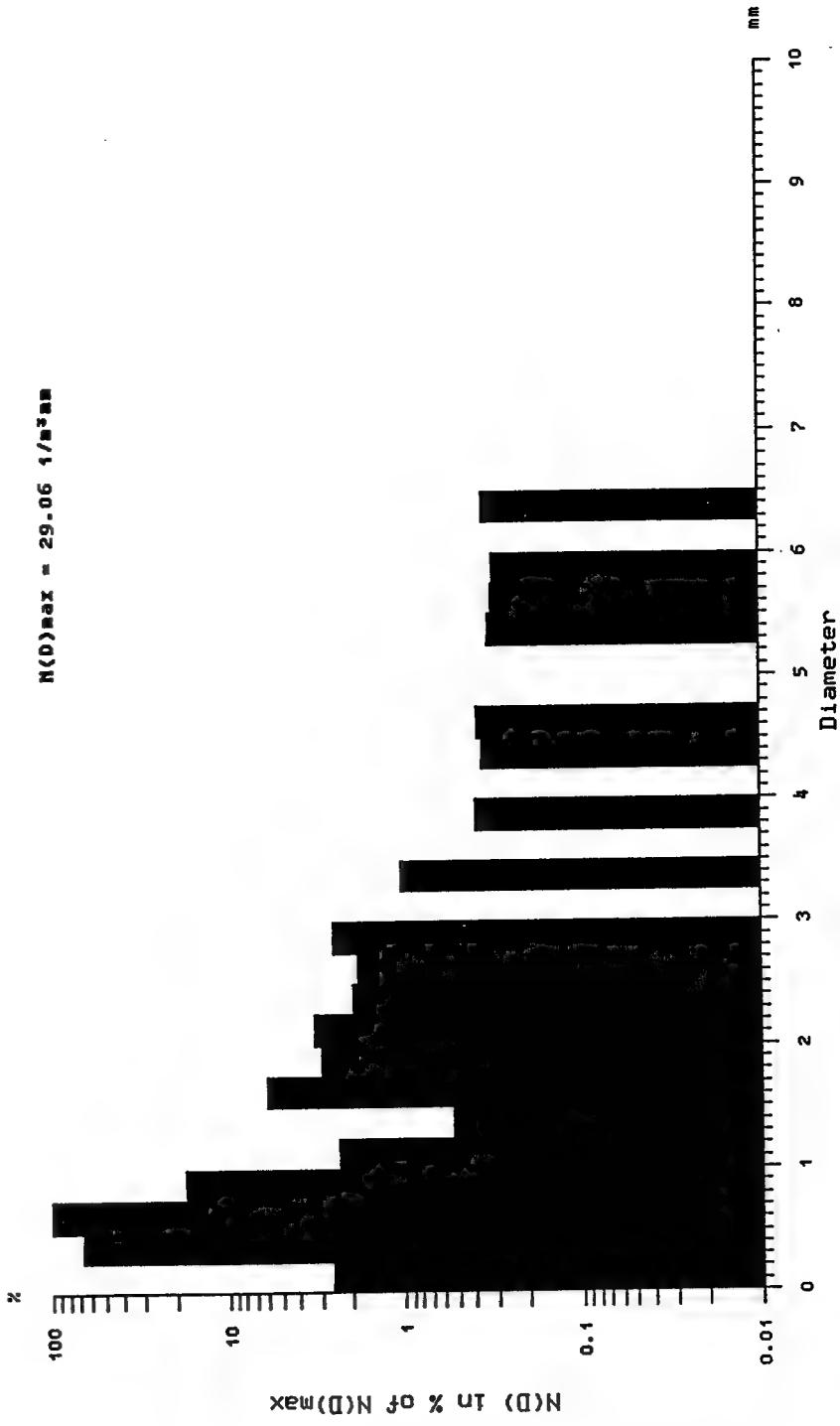


JOANNEUM RESEARCH - ESA		2D-Video-Distrometer		Graz/Austria		Mon Jun 24 1996	
File	v96176_2.hyd	Time	17:03 - 18:00	Diameter	0.00 mm	50.00 mm	
Int.	17:03:00-17:12:40	Date	Jun 24 1996	Velocity	0.00 m/s	30.00 m/s	
Rain	0.09 mm			Oblateness	0.00	2.00	
Time Int	580.00 s	Rainrate	0.58 mm/h	Pixel A	0	511	
Objects	176	AD	0.25 mm	Pixel B	0	511	

<input type="checkbox"/>	MAIN
<input type="checkbox"/>	HARDCOPY
<input type="checkbox"/>	HELP
<input type="checkbox"/>	F4
<input type="checkbox"/>	F3
<input type="checkbox"/>	COMP
<input type="checkbox"/>	Integr.
<input type="checkbox"/>	F7
<input type="checkbox"/>	F8

### Drop Size Distribution

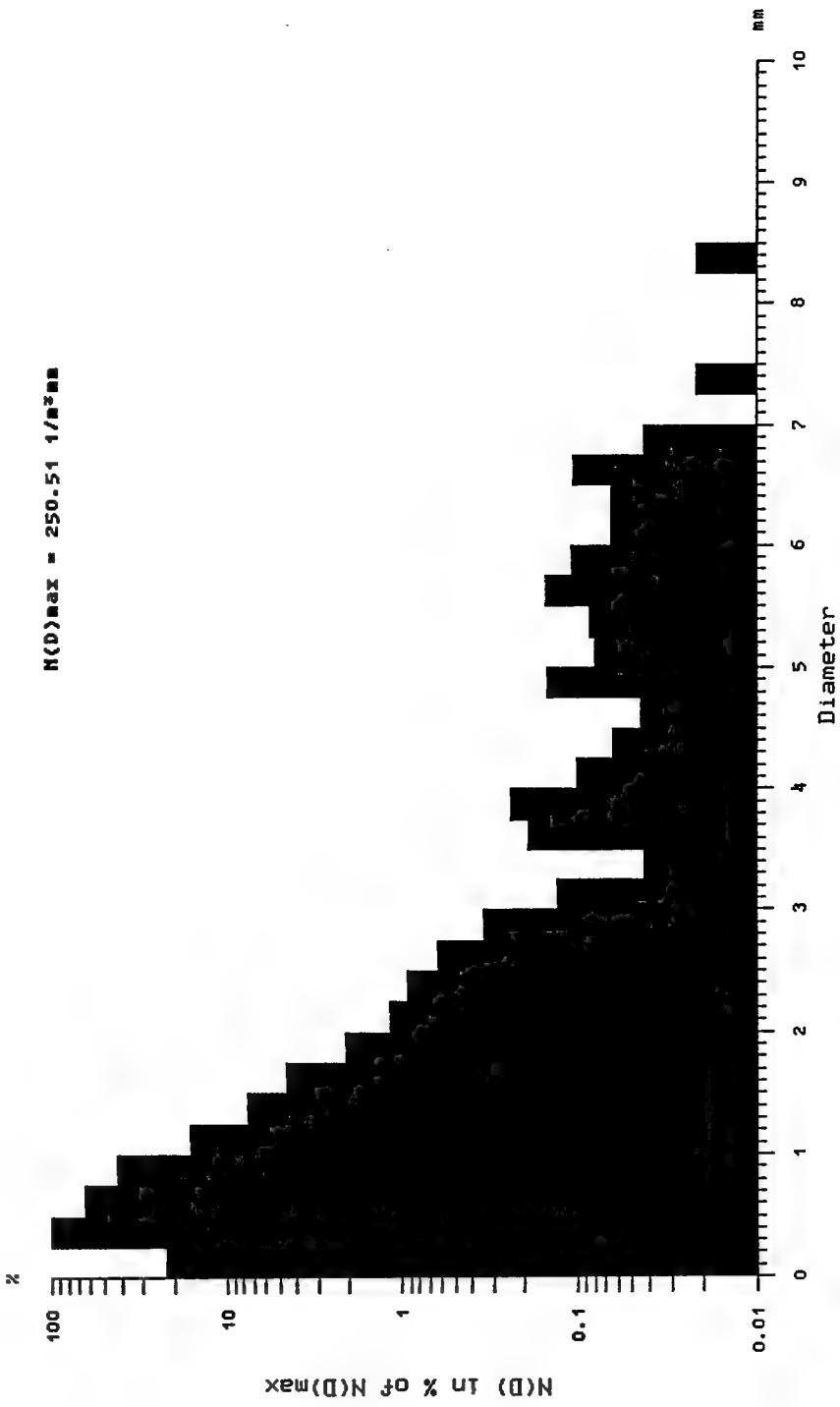
$$N(D)_{\text{max}} = 29.06 \text{ 1/mm}^3$$



Date: June 24, 1996  
Julian Day: 176  
Event: 2  
Time: 18:23-18:38  
Average Rain Rate: 3.27mm\hr  
Total Rainfall: .84mm  
Location: Lat.- 40:19:35  
                  Lon.-104:33:52  
Contents: Light rain

JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria						Mon Jun 24 1996					
File	v96176_3-hyd	Int.	16:23:00-18:38:30	Date	Jun 24 1996	Time	18:23 - 19:00	Diameter	0.00 mm	50.00 mm	50.00 mm	MAIN	RUN	MAIN	RUN	MAIN	RUN	MAIN	RUN	MAIN	RUN	MAIN	RUN
Rain	0.84 mm							Velocity	0.00 m/s	30.00 m/s	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	
Time Int	930.00 s							Oblateness	0.00	2.00													
Pixel A								Pixel A	0	511													
Pixel B								Pixel B	0	511													
Objects	2610							AD	0.25 mm														

Drop Size Distribution



Date: June 24, 1996

Julian Day: 176

Event: 3

Time: 19:06-19:56

Average Rain Rate: 11.75mm\hr

Total Rainfall: 9.79mm

Location: Lat.- 40:17:08  
Lon.-104:33:55  
Facing east

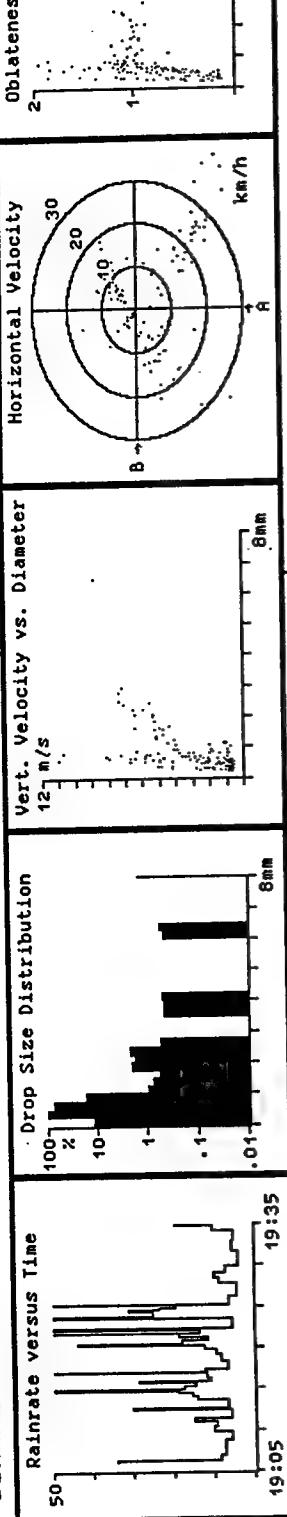
Contents: A lot of hail in the first twenty minutes  
pea and marble sized hail  
Heavy rains  
Southeasterly winds  
Some van scans

## JOANNEUM RESEARCH - ESA

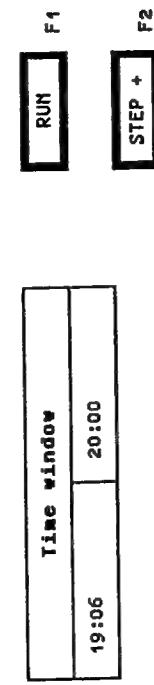
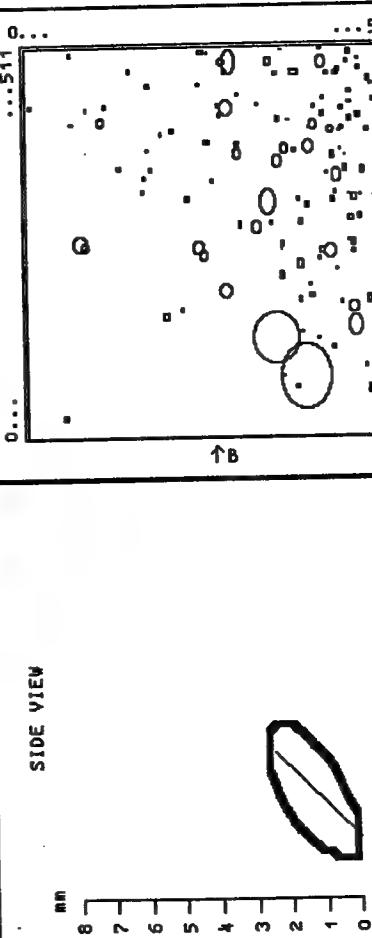
## 2D-Video-Distrometer

Graz/Austria

Mon Jun 24 1996



SIDE VIEW



Filter - Diameter

0.00 mm	50.00 mm
---------	----------

Filter - Velocity

0.00 m/s	30.00 m/s
----------	-----------

Filter - Oblateness

0.00	2.00
------	------

FRONT VIEW

Time	19:36:01.392
Eq. Diameter	2.96 mm
Ver. Velocity	7.2 m/s
Oblateness	0.96
Hor. Velocity	42.1 km/h, 121.8°
Wind Sensor	-----
Temperature	-----
Type	not class.
Area	9599.49 mm <sup>2</sup>
v96176_hydr	90392:2159030

Filter - Pixel System A

0	511
---	-----

Filter - Pixel System B

0	511
---	-----

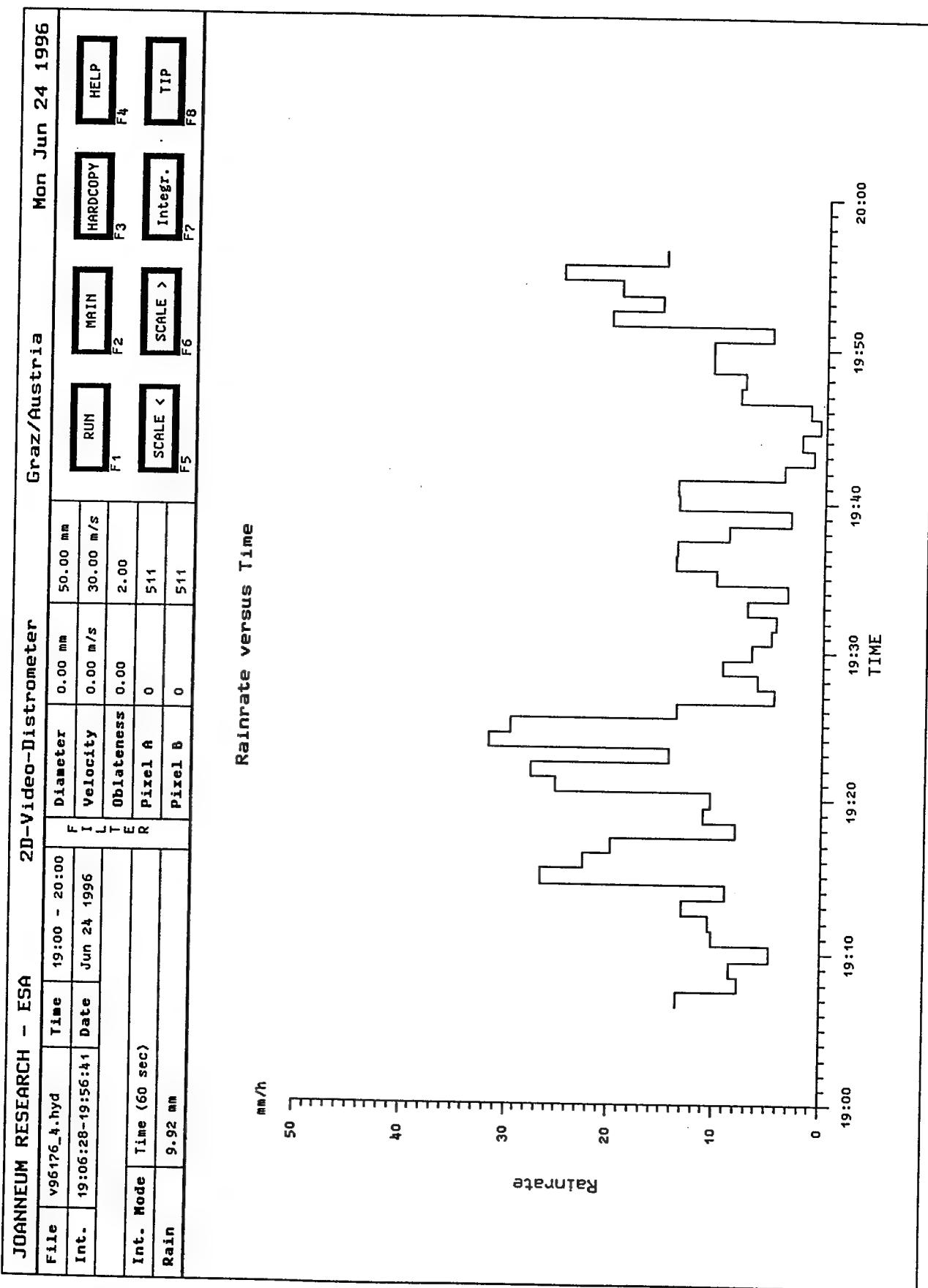
Filter - Pixel System C

0	2.00
---	------

QUIT ESC

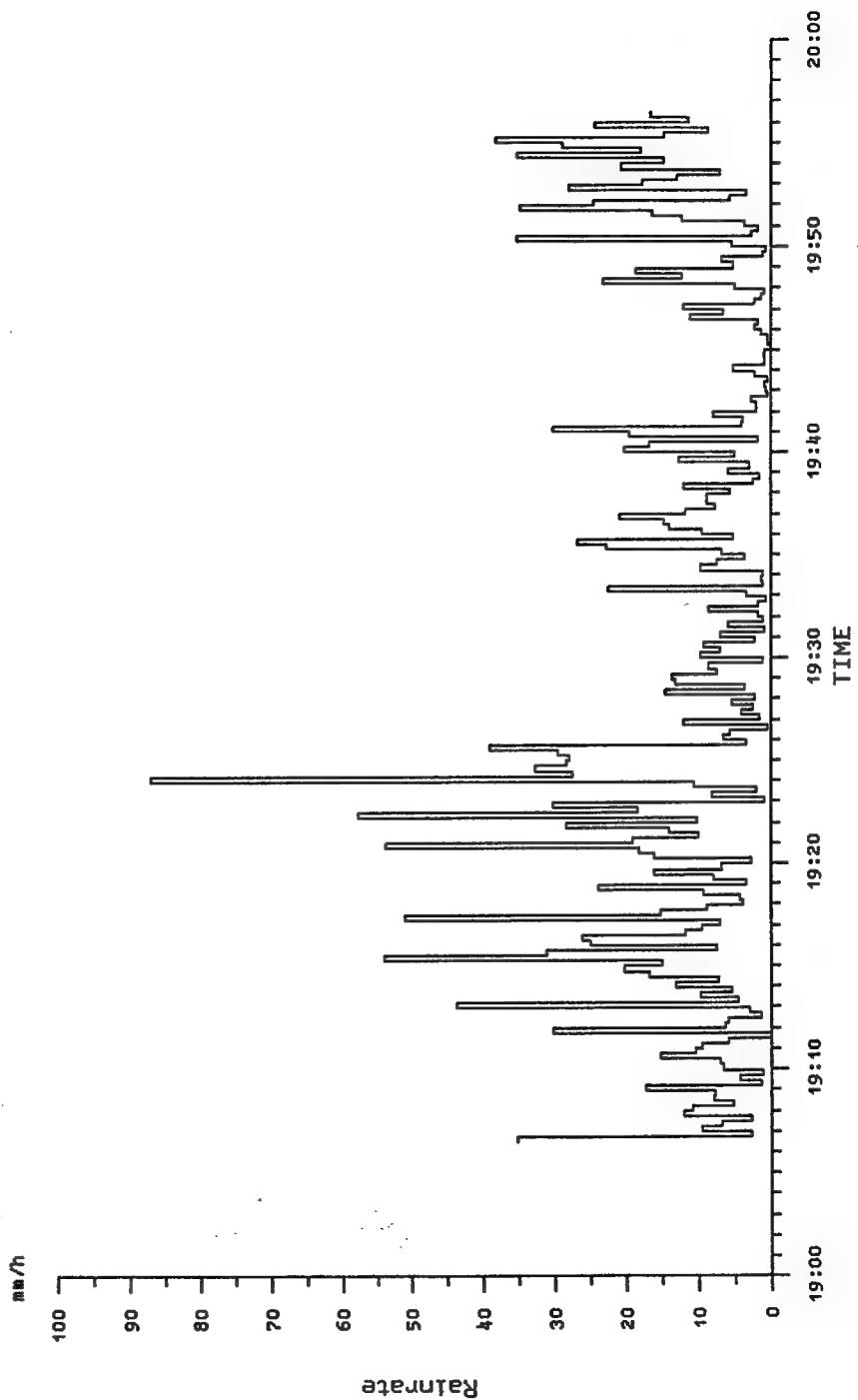
Area display mode

Position / Size
Distribution



JOANNEUM RESEARCH - ESA						2D-Video-Distrrometer						Graz/Austria					
File	v96176_4.hyd	Time	19:00 - 20:00	Diameter	0.00 mm	50.00 mm	50.00 mm	MAIN	HELP	MAIN	HELP	MAIN	HELP	MAIN	HELP	MAIN	HELP
Int.	19:06:28-19:56:41	Date	Jun 24 1996	F	Velocity	0.00 m/s	30.00 m/s	F1	F4	F2	F3	F1	F4	F2	F3	F1	F4
				L	Oblateness	0.00	2.00										
				E	R Pixel A	0	511										
				R	Pixel B	0	511										
Int. Mode	Time (15 SEC)							SCALE <	SCALE >	SCALE <	SCALE >	SCALE <	SCALE >	SCALE <	SCALE >	SCALE <	SCALE >
Rain	9.92 mm							F5	F6	F5	F6	F5	F6	F5	F6	F5	F6

Rainrate versus Time

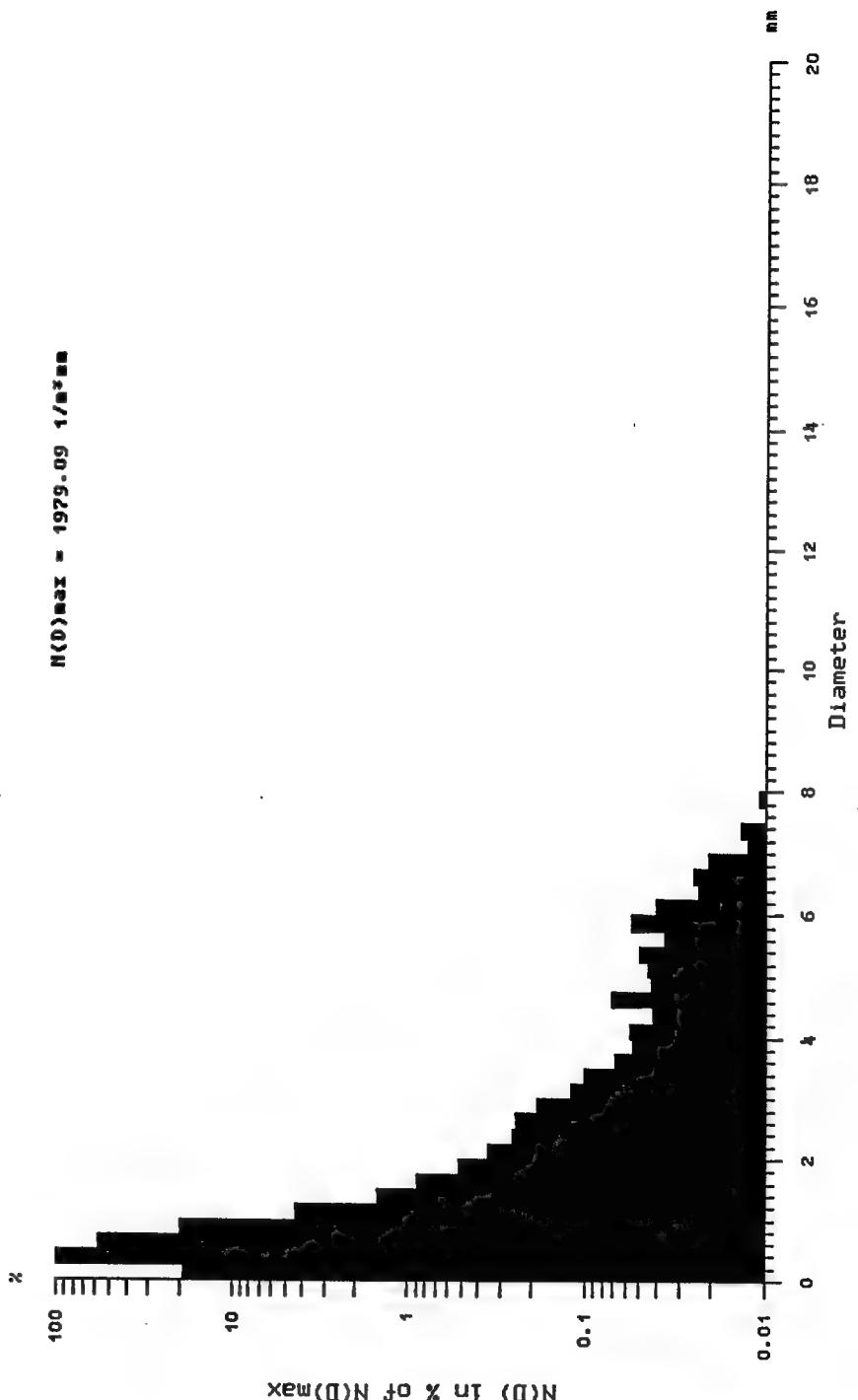


JOANNEUM RESEARCH - ESA				2D-Video-Distrrometer				Graz/Austria				Mon Jun 24 1996			
File	v96176_4.hyd	Time	19:06 - 20:00	F	Diameter	0.00 mm	50.00 mm								
Int.	19:06:00-19:56:00	Date	Jun 24 1996	I	Velocity	0.00 m/s	30.00 m/s								
Rain	9.79 mm			L	Oblateness	0.00	2.00								
Time Int	3000.00 s	Rainrate	11.75 mm/h	R	Pixel A	0	511								
Objects	39202	AD	0.25 mm	R	Pixel B	0	511								

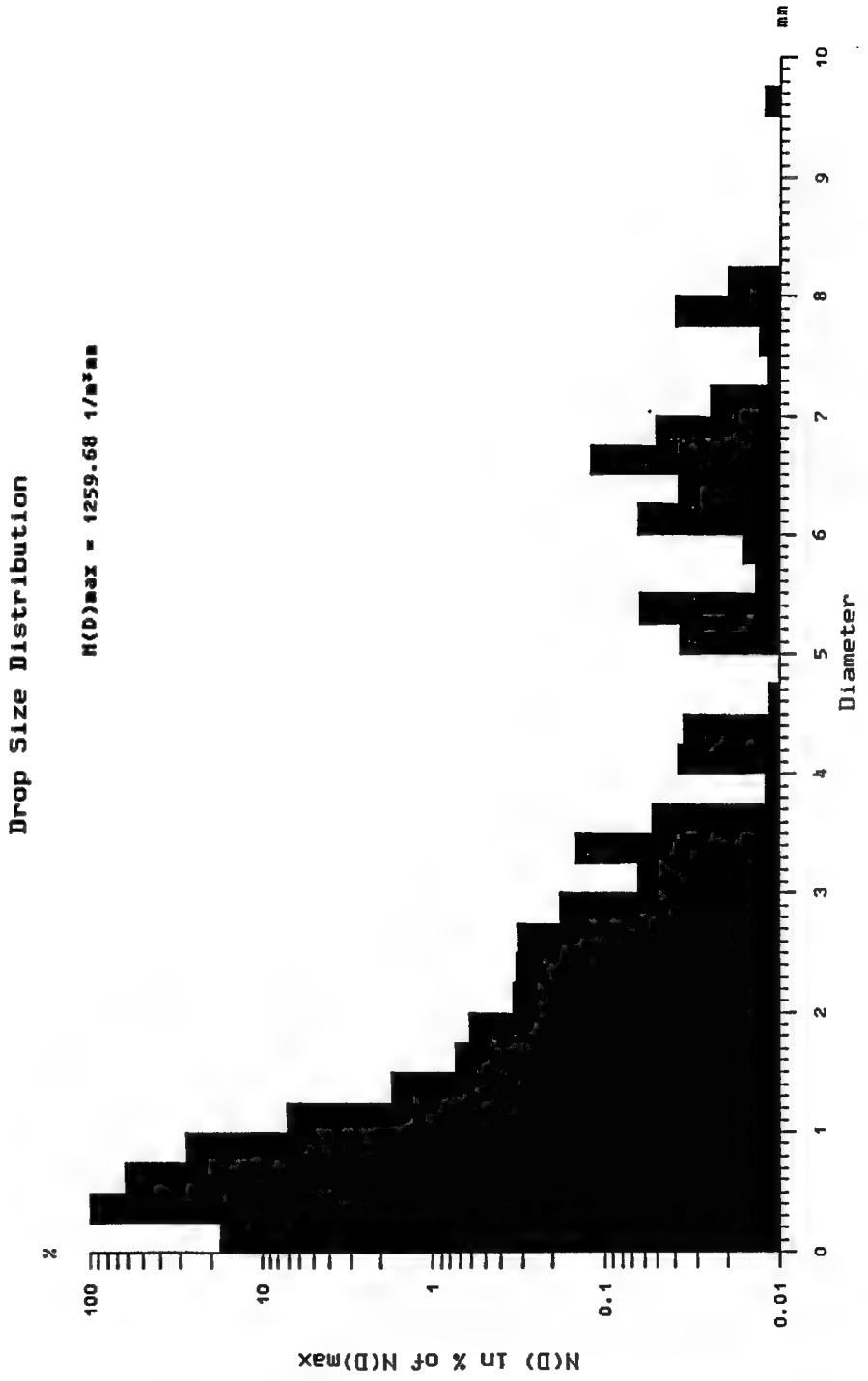
<input type="button" value="RUN"/>	<input type="button" value="MAIN"/>	<input type="button" value="HARDCOPY"/>	<input type="button" value="HELP"/>
<input type="button" value="F1"/>	<input type="button" value="F2"/>	<input type="button" value="F3"/>	<input type="button" value="F4"/>
<input type="button" value="AD &lt;"/>	<input type="button" value="AD &gt;"/>	<input type="button" value="Integr."/>	<input type="button" value="COMP"/>
<input type="button" value="F5"/>	<input type="button" value="F6"/>	<input type="button" value="F7"/>	<input type="button" value="F8"/>

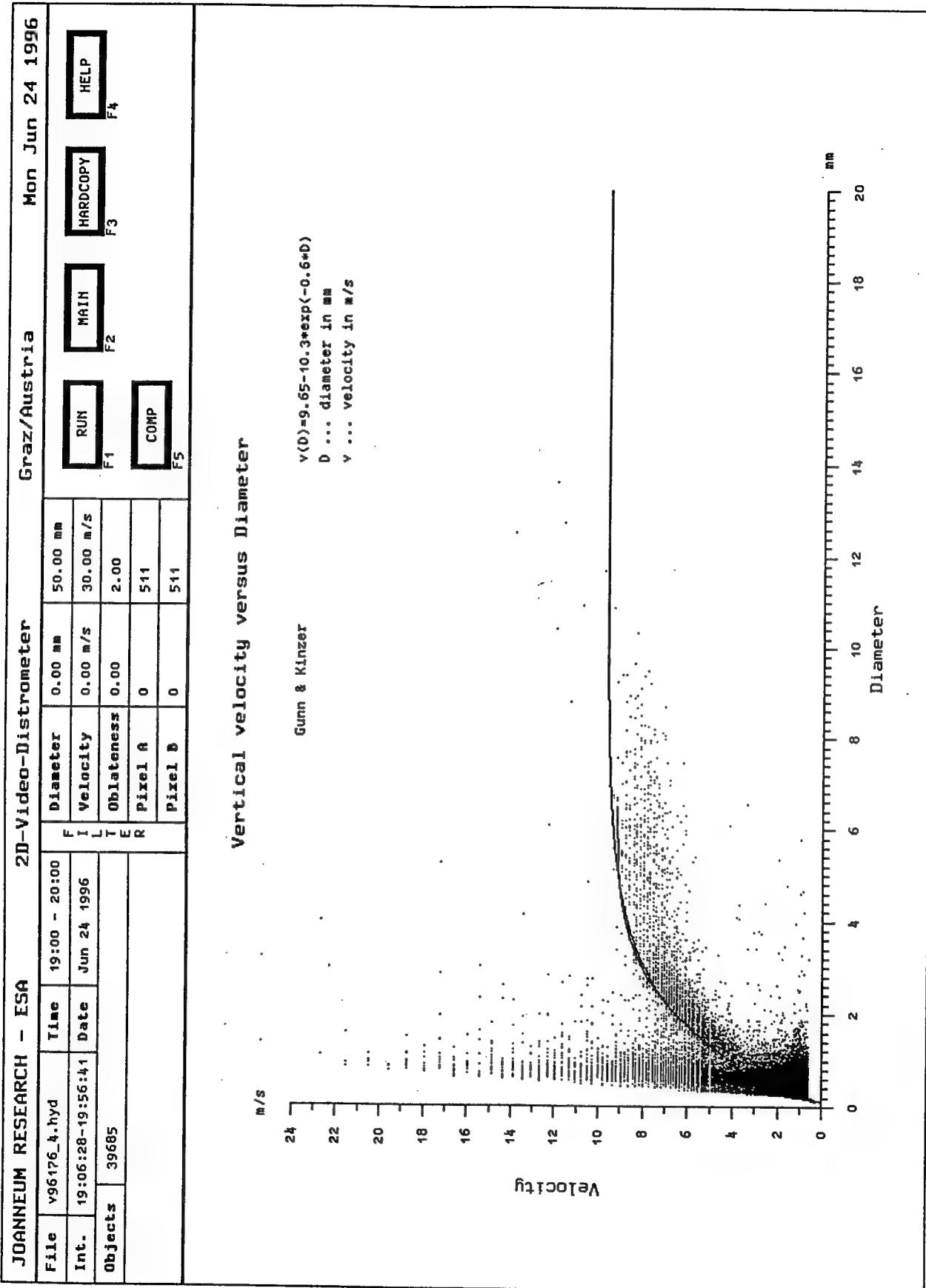
Drop Size Distribution

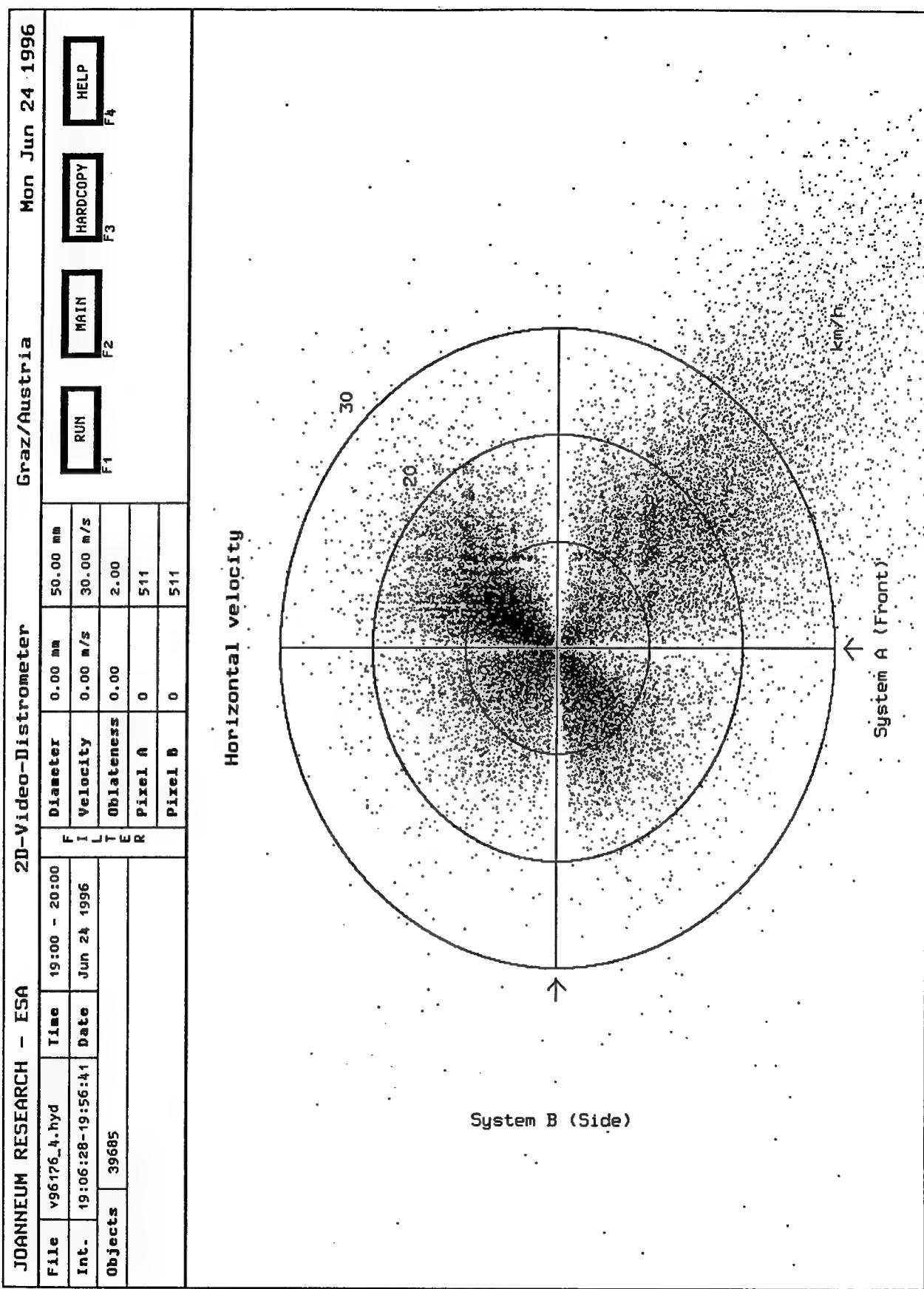
$N(D)_{\text{MAX}} = 1979.09 \text{ 1/mm}^3$



JOANNEUM RESEARCH - ESA				2D-Video-Distrrometer				Graz/Austria				Mon Jun 24 1996			
File	v96176.4.hyd	Time	19:00 - 20:00	Diameter	0.00 mm	50.00 mm		RUN	MAIN	HARDCOPY	HELP				
Int.	19:06:00-19:12:00	Date	Jun 24 1996	Velocity	0.00 m/s	30.00 m/s		F1	F2	F3	F4				
Rain	0.88 mm			Oblateness	0.00	2.00									
Time Int	360.00 s	Rainrate	8.82 mm/h	Pixel A	0	511		AD <	AD >	Integr.	COMP				
Objects	3443	AD	0.25 mm	Pixel B	0	511		F5	F6	F7	F8				







JOANNEUM RESEARCH - ESA  
2D-Video-Distrometer

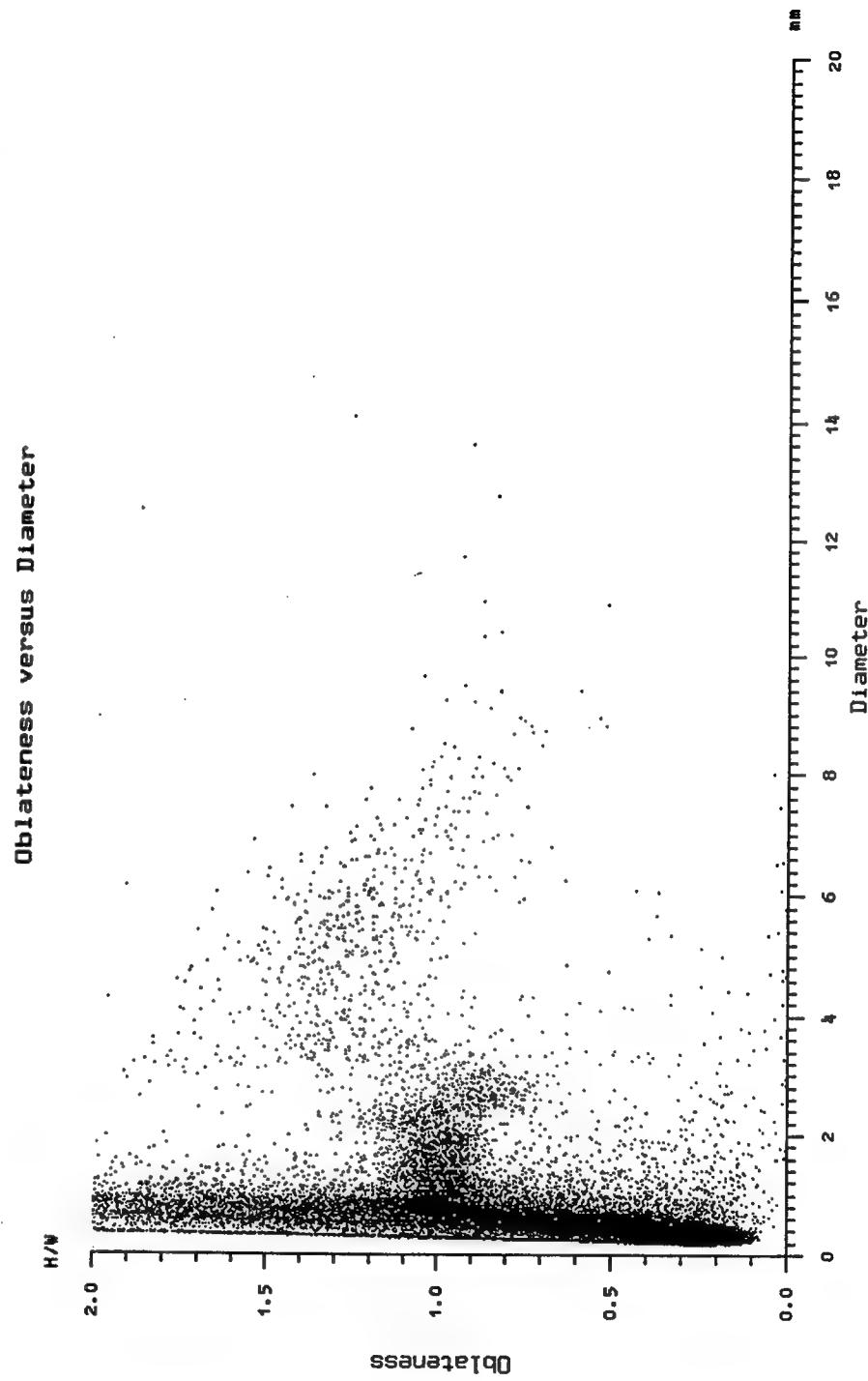
File	v96175_t.hyd	Time	19:00 - 20:00	Diameter	0.00 mm	50.00 mm
Int.	19:06:28-19:56:41	Date	Jun 24 1996	Velocity	0.00 m/s	30.00 m/s
Objects	39685			Oblateness	0.00	2.00
				Pixel A	0	511
				Pixel B	0	511

Graz/Austria

Mon Jun 24 1996

**RUN** **MAIN** **HARDCOPY** **HELP**  
F1 F2 F3 F4

**COMP** **GRID** **N(H/W)**  
F5 F6 F7



JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria				Mon Jun 24 1996			
File	v96176.4.hyd	Time	19:00 - 20:00	F	Diameter	5.00 mm	50.00 mm								
Hyd. Time	19:10:33.397	Date	Jun 24 1996	I	Velocity	0.00 m/s	30.00 m/s								
Eq. Diam.	9.66 mm	Velocity	8.45 m/s	L	Oblateness	0.00	2.00								
Obl.ness	1.04	Type	not class.	R	Pixel A	0	511								
				P	Pixel B	0	511								

<input type="button" value="STEP +"/>	<input type="button" value="MAIN"/>	<input type="button" value="HARDCOPY"/>	<input type="button" value="HELP"/>
<input type="button" value="F1"/>	<input type="button" value="F2"/>	<input type="button" value="F3"/>	<input type="button" value="F4"/>
<input type="button" value="STEP -"/>	<input type="button" value="ASCII"/>	<input type="button" value="CORR"/>	
<input type="button" value="F5"/>	<input type="button" value="F6"/>	<input type="button" value="F7"/>	

#### FRONT VIEW

Oblateness front 1.04

Height front 9.84 mm

Width front 9.74 mm

Horiz. velocity 44.33 m/h (+)

mm

mm

75

#### SIDE VIEW

Oblateness side 1.08

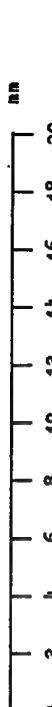
Height side 10.08 mm

Width side 9.35 mm

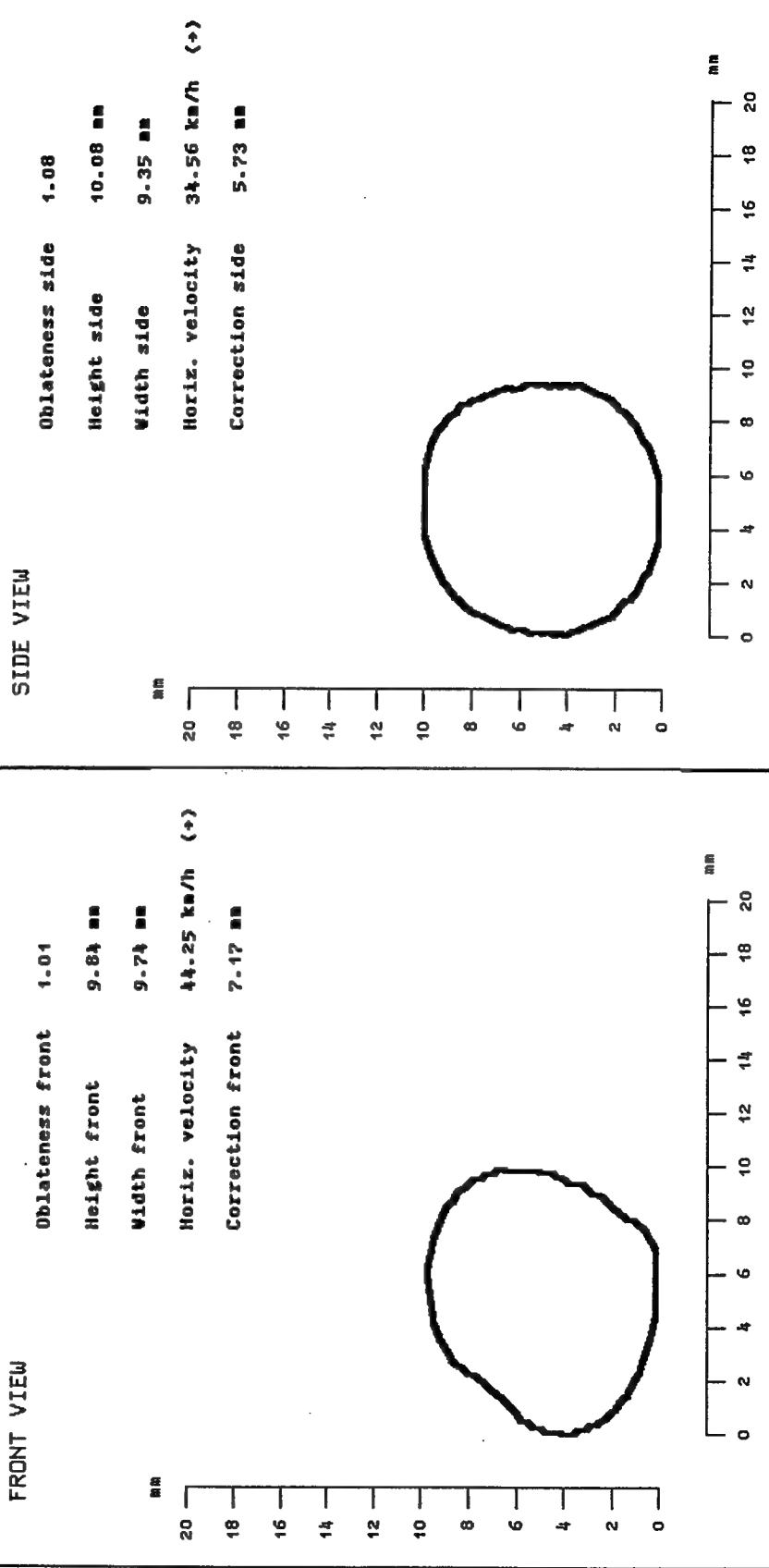
Horiz. velocity 34.56 m/h (+)

mm

mm



JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria		Mon Jun 24 1996	
File	v96126_4.hyd	Time	19:00 - 20:00	Diameter	5.00 mm	50.00 mm		STEP +	MAIN	HARDCOPY	HELP
Hyd.	Time	19:10:33.397	Date	Jun 24 1996	Velocity	0.00 m/s	30.00 m/s	F1	F2	F3	F4
Eq.Diam.	9.66 mm	Velocity	8.45 m/s	Oblateness	0.00	2.00					
Obl.ness	1.04	Type	not class.	Pixel A	0	511	STEP -	ASCII	CORR		
Views corrected :		Pixel B	0	Pixel C	0	511	F5	F6	F7		



Date: June 28, 1996

Julian Day: 180

Event: 1

Time: 15:26-15:35

Average Rain Rate: 13.86mm\hr

Total Rainfall: 2.08mm

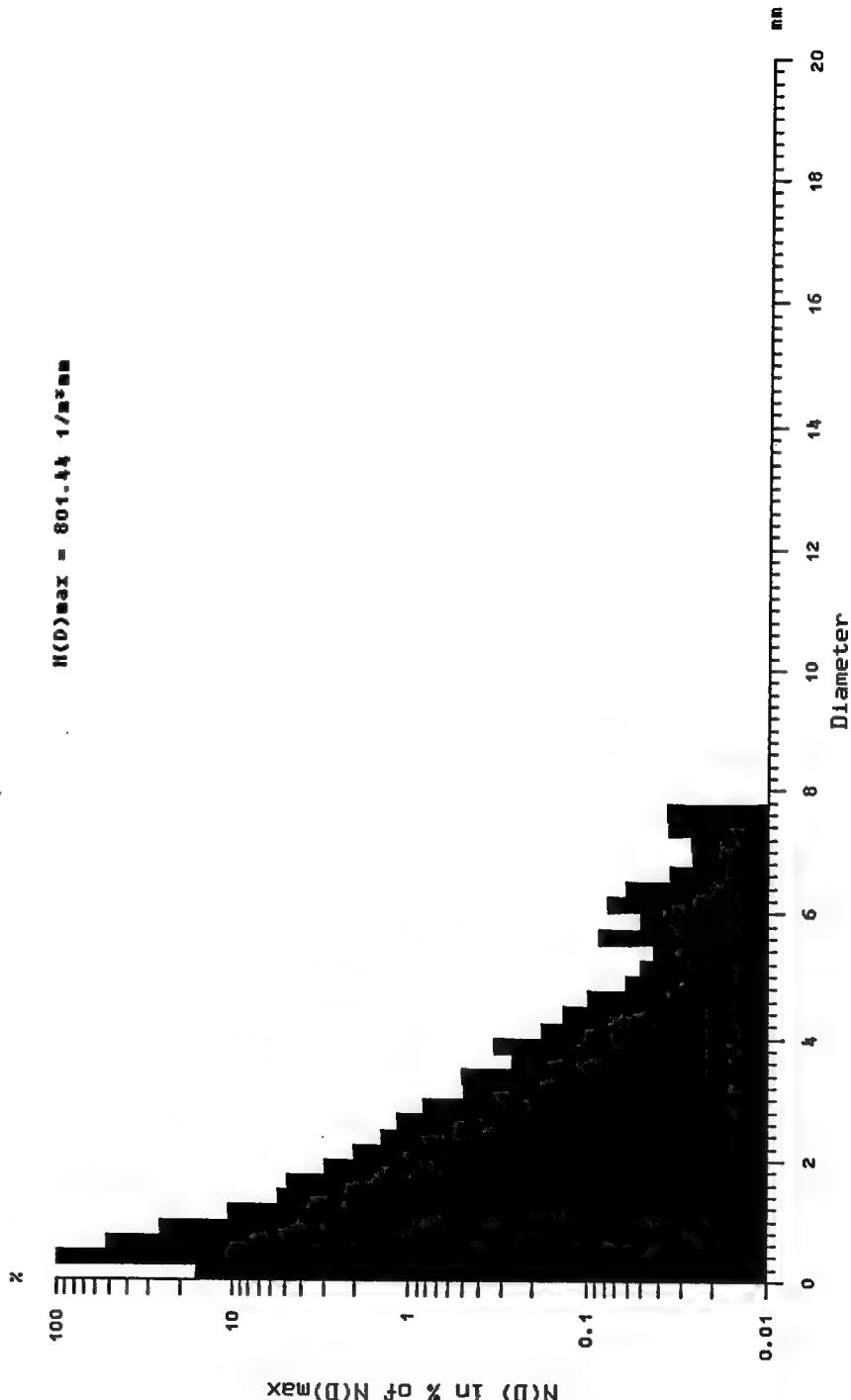
Location: I-25 & highway 34  
Lat.- 40:24:25  
Lon.-104:59:47

Contents: Moderate rain  
No large drops

JOANNEUM RESEARCH - ESA				2D-Video-Distrrometer				Graz/Austria				Sat Jul 6 1996			
File	996188_2.hyd	Time	16:18 - 17:00	Diameter	0.00 mm	50.00 mm		Run	Main	Hardcopy	Help				
Int.	16:18:00-16:29:00	Date	Jul 6 1996	F	0.00 m/s	30.00 m/s		F1	F2	F3	F4				
Rain	2.29 mm			L	Oblateness	0.00									
Time Int	660.00 s	Rainrate	12.51 mm/h	R	Pixel A	0	511								
Objects	5260	4D	0.25 mm	Pixel B	0	511		AD <	AD >	Integr.	COMP				
								F5	F6	F7	F8				

### Drop Size Distribution

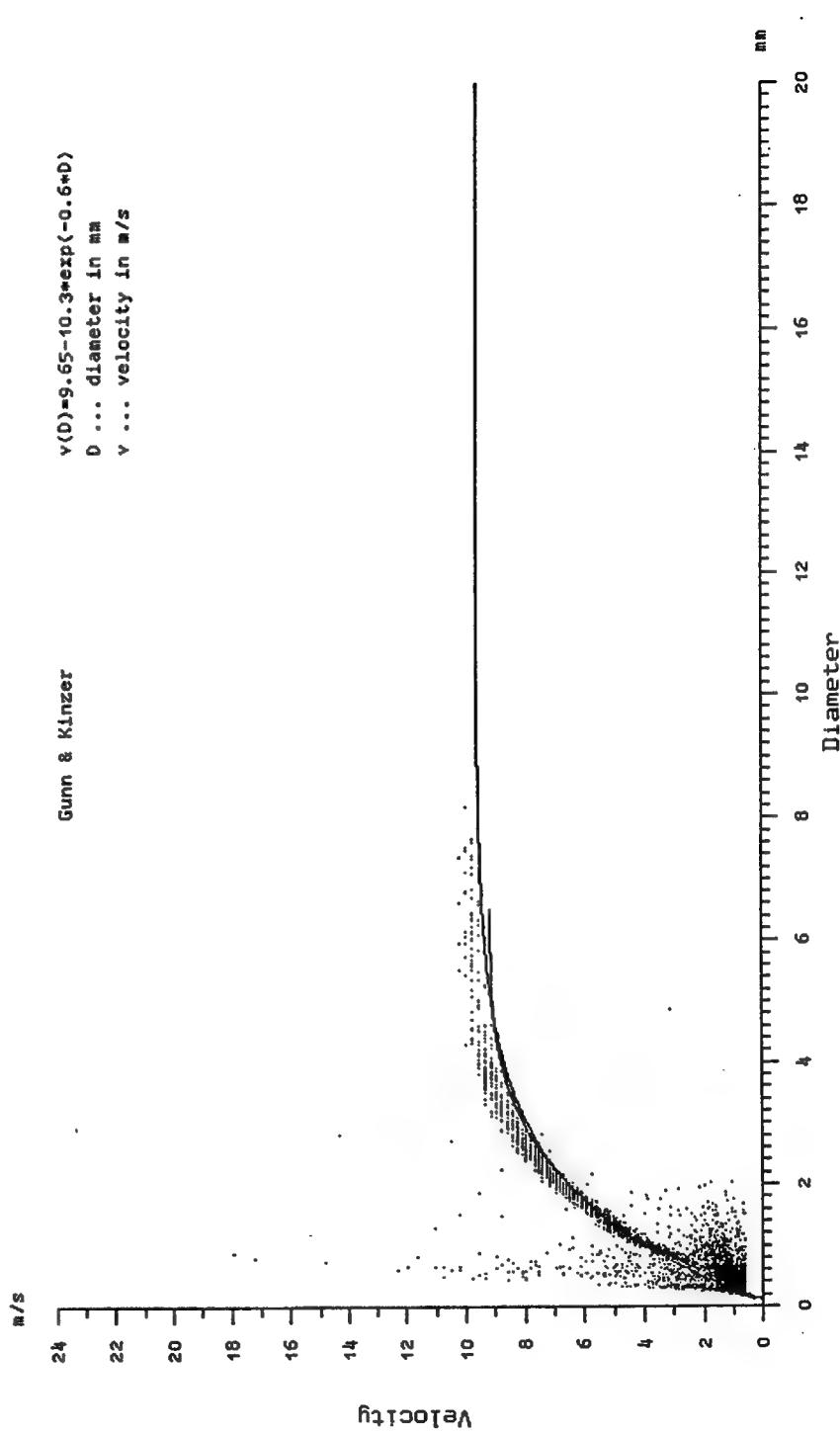
$$N(D)_{\text{max}} = 801.44 \text{ 1/mm}^3$$

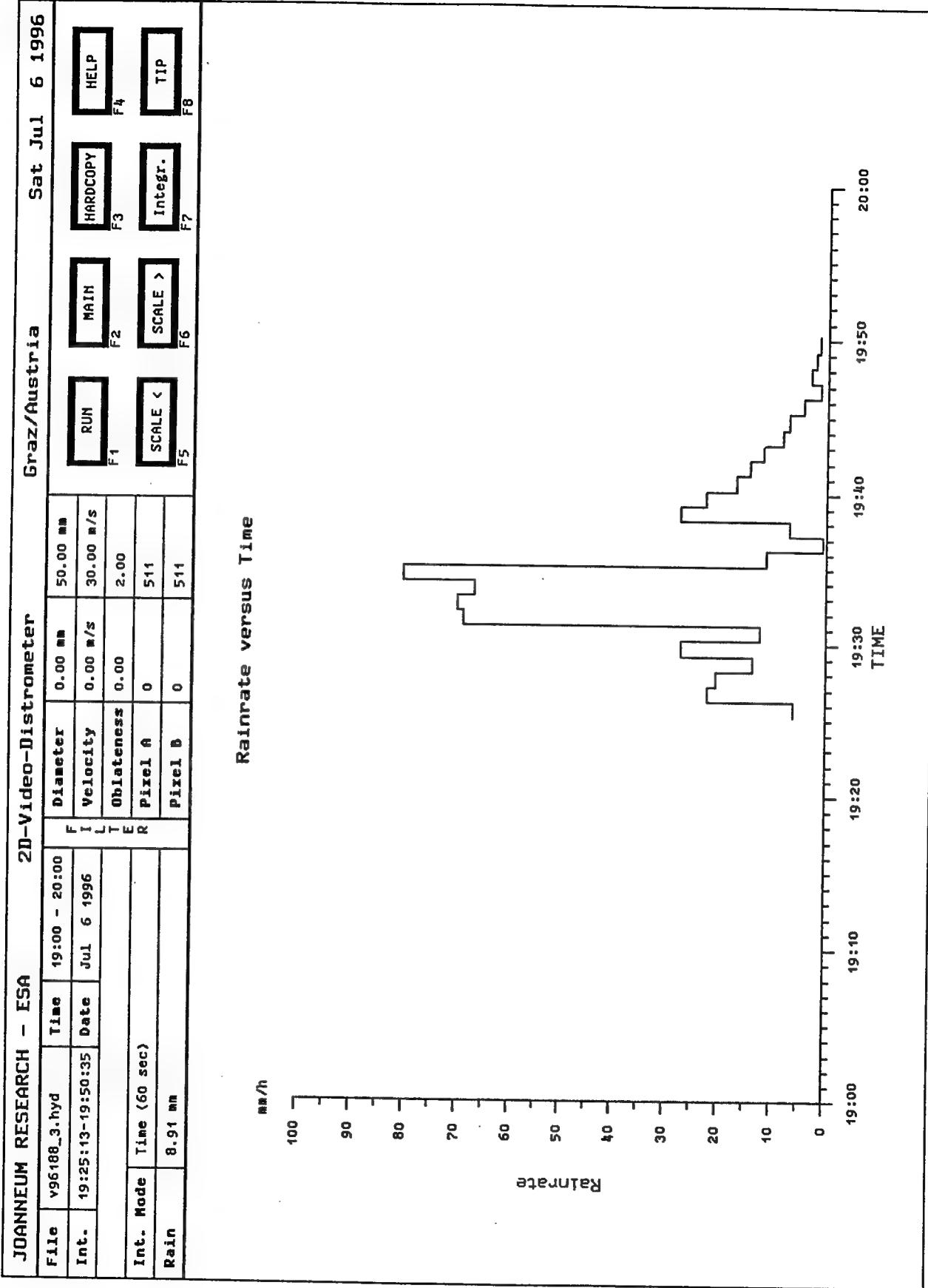


JOANNEUM RESEARCH - ESA				2D-Video-Distrometer				Graz/Austria				Sat Jul 6 1996	
File	v96168_2.hyd	Time	16:18 - 17:00	F	Diameter	0.00 mm	50.00 mm						
Int.	16:18:40-16:29:14	Date	Jul 6 1996	I	Velocity	0.00 m/s	30.00 m/s						
Objects	5315			L	Oblateness	0.00	2.00						
				E	Pixel A	0	511						
				R	Pixel B	0	511						



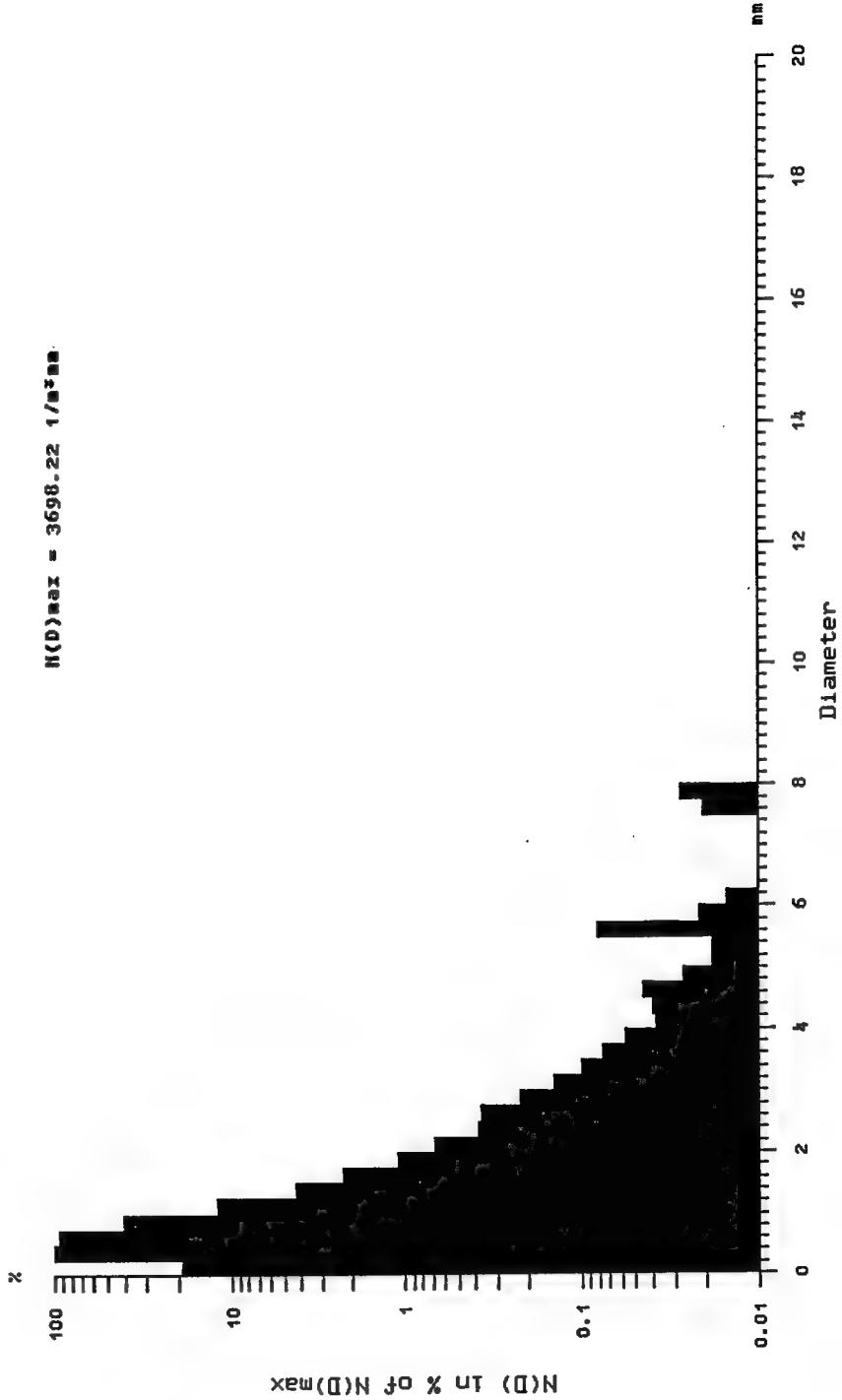
Vertical velocity versus Diameter

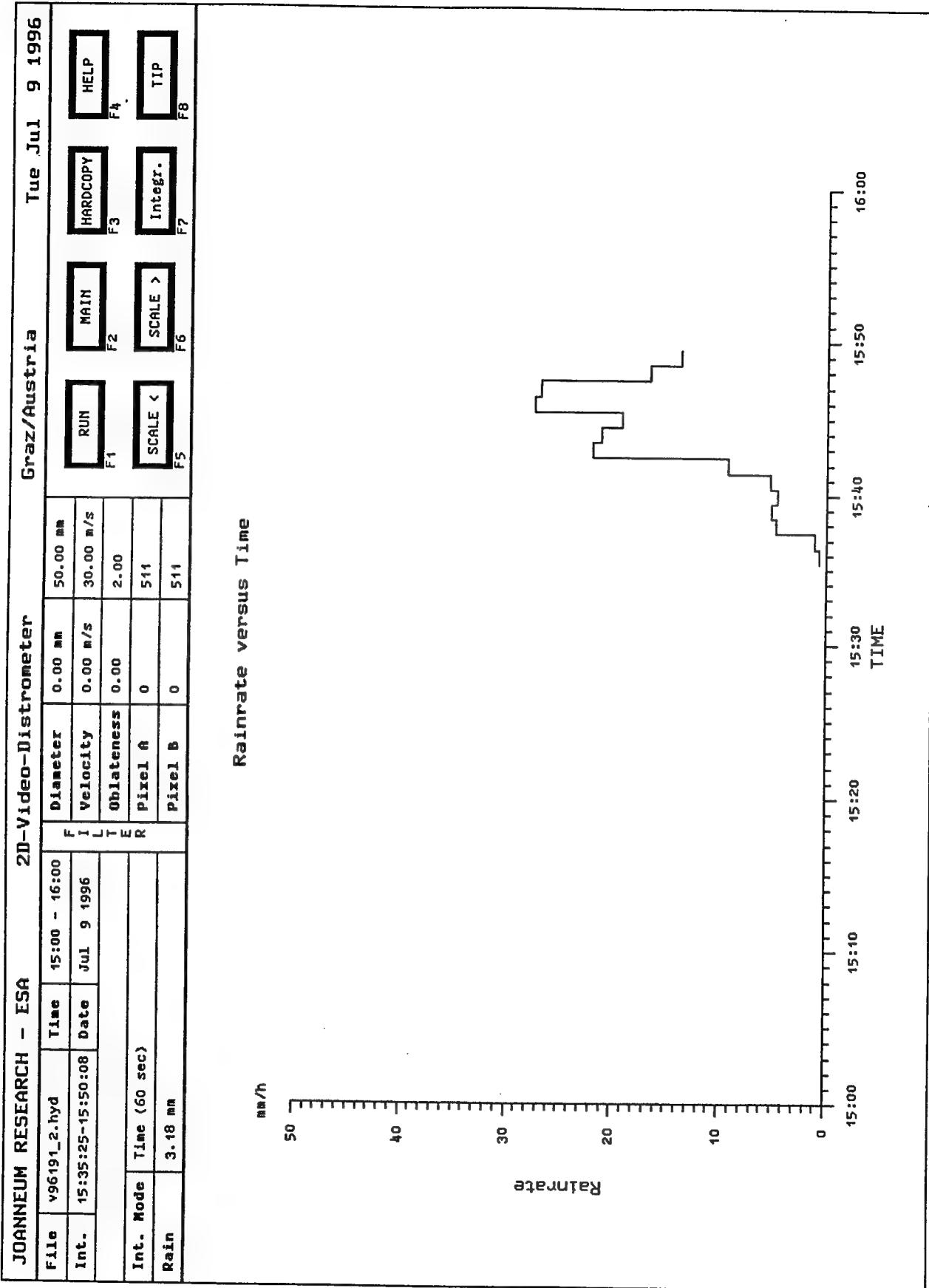




JOANNEUM RESEARCH - EEA		2D-Video-Distrometer		Graz/Austria		Sat Jul 6 1996	
File	v96188_3.hyd	Time	19:25 - 20:00	Diameter	0.00 mm	50.00 mm	
Int.	19:25:00-19:50:30	Date	Jul 6 1996	F			
Rain	8.90 mm			I	Velocity	0.00 m/s	
Time Int	1530.00 s	Rainrate	20.95 mm/h	L		30.00 m/s	
Objects	50861	AD	0.25 mm	E	Oblateness	0.00	
				R	Pixel A	0	
					Pixel B	0	
						511	
				F5			

Drop Size Distribution





Date: July 9, 1996

Julian Day: 191

Event: 2

Time: 18:35-19:05

Average Rain Rate: 13.62mm\hr

Total Rainfall: 6.13mm

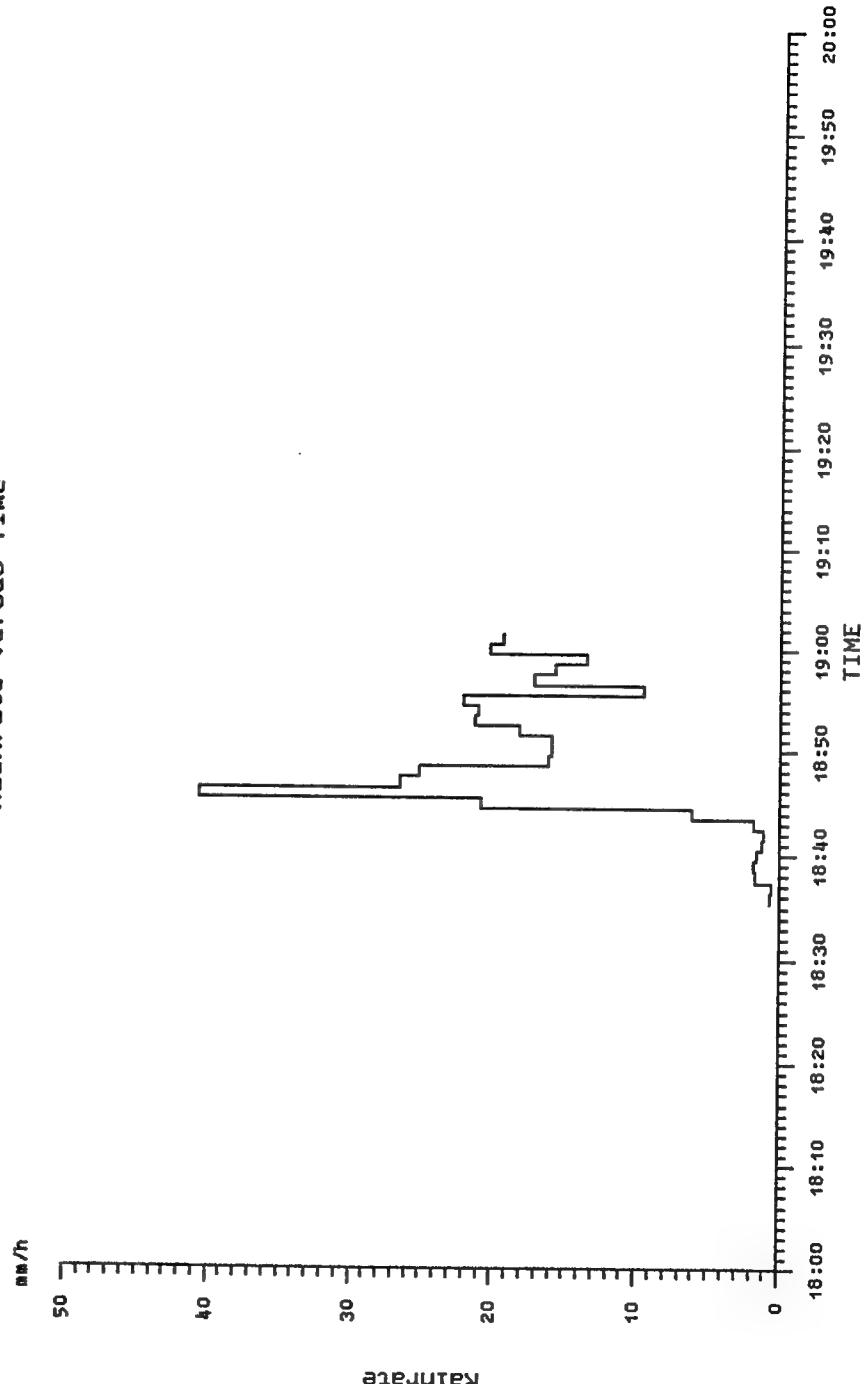
Location: Lat.- 40:29:39  
Lon.-104:59:58

Contents: Light drizzle  
18:43- moderate rain with large drops  
18:45- heavy rain with very large drops

JOANNEUM RESEARCH - Esa						2D-Video-Distrrometer						Graz/Austria						Tue Jul 9 1996							
File	v96191_3.hyd	Time	18:00 - 20:00	F	Diameter	0.00 mm	50.00 mm		RUN																
Int.	18:35:28-19:02:08	Date	Jul 9 1996	I	Velocity	0.00 m/s	30.00 m/s																		
				L	Oblateness	0.00	2.00																		
Int. Mode	Time (60 sec)	R	Pixel A	0	511																				
Rain	6.17 mm	Pixel B	0	511																					

<input type="button" value="HELP"/>	<input type="button" value="HARDCOPY"/>
<input type="button" value="MAIN"/>	<input type="button" value="F2"/>
<input type="button" value="RUN"/>	<input type="button" value="F1"/>
<input type="button" value="SCALE &gt;"/>	<input type="button" value="F6"/>
<input type="button" value="SCALE &lt;"/>	<input type="button" value="F7"/>
<input type="button" value="Integr."/>	<input type="button" value="F8"/>
<input type="button" value="TIP"/>	

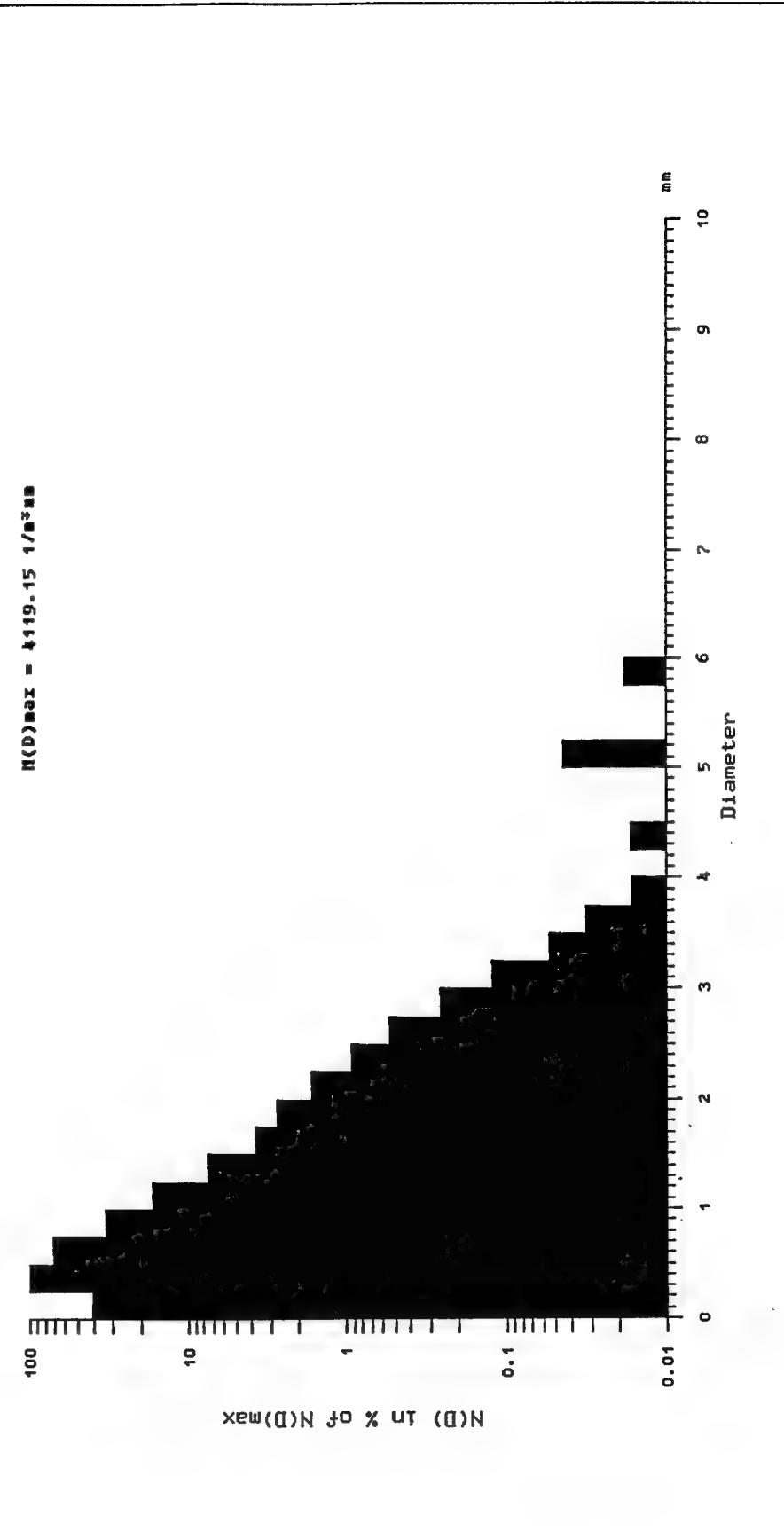
Rainrate versus Time



JOANNEUM RESEARCH - ESA						2D-Video-Distrrometer						Graz/Austria						Tue Jul 9 1996					
File	v96191_3.Myd	Time	18:35 - 20:00	Diameter	0.00 mm	50.00 mm	50.00 mm	MAIN	HARDCOPY	HELP	F1	F2	F3	F4	F5	F6	F7	F8	F1	F2	F3	F4	
Int.	18:35:00-19:02:00	Date	Jul 9 1996	Velocity	0.00 m/s	30.00 m/s	30.00 m/s	RUN															
Rain	6.13 mm			Oblateness	0.00	2.00																	
Time Int	1620.00 s	Rainrate	13.62 mm/h	Pixel A	0	511																	
Objects	64691	AD	0.25 mm	Pixel B	0	511																	

### Drop Size Distribution

$$N(D)_{\text{max}} = 4119.15 \text{ 1/mm}^3$$



Date: July 13, 1996

Julian Day: 195

Event: 1

Time: 14:27-14:50

Average Rain Rate: 22.7mm\hr

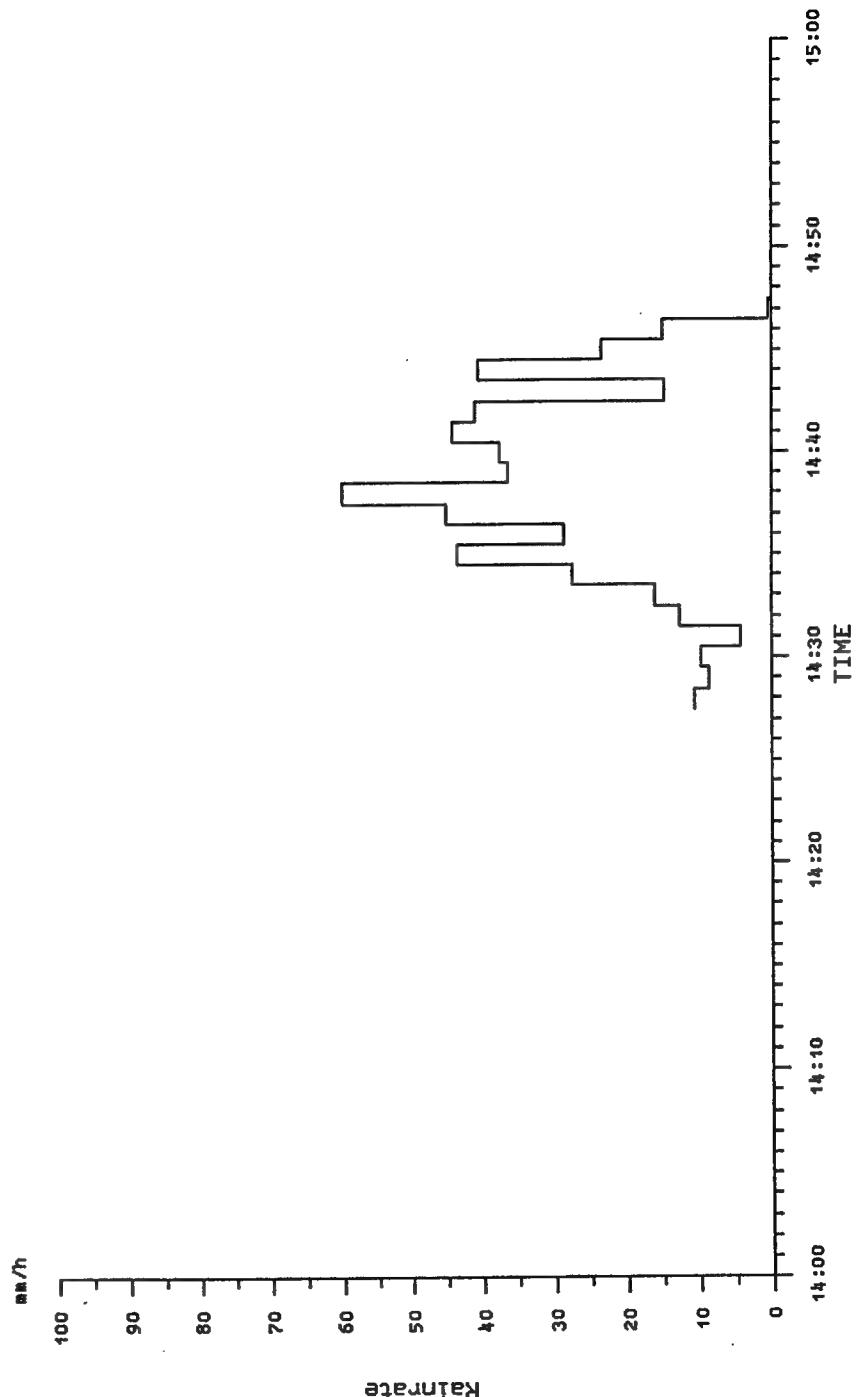
Total Rainfall: 8.7mm

Location: Lat.- 40:42:42  
Lon.-104:55:32  
Facing east

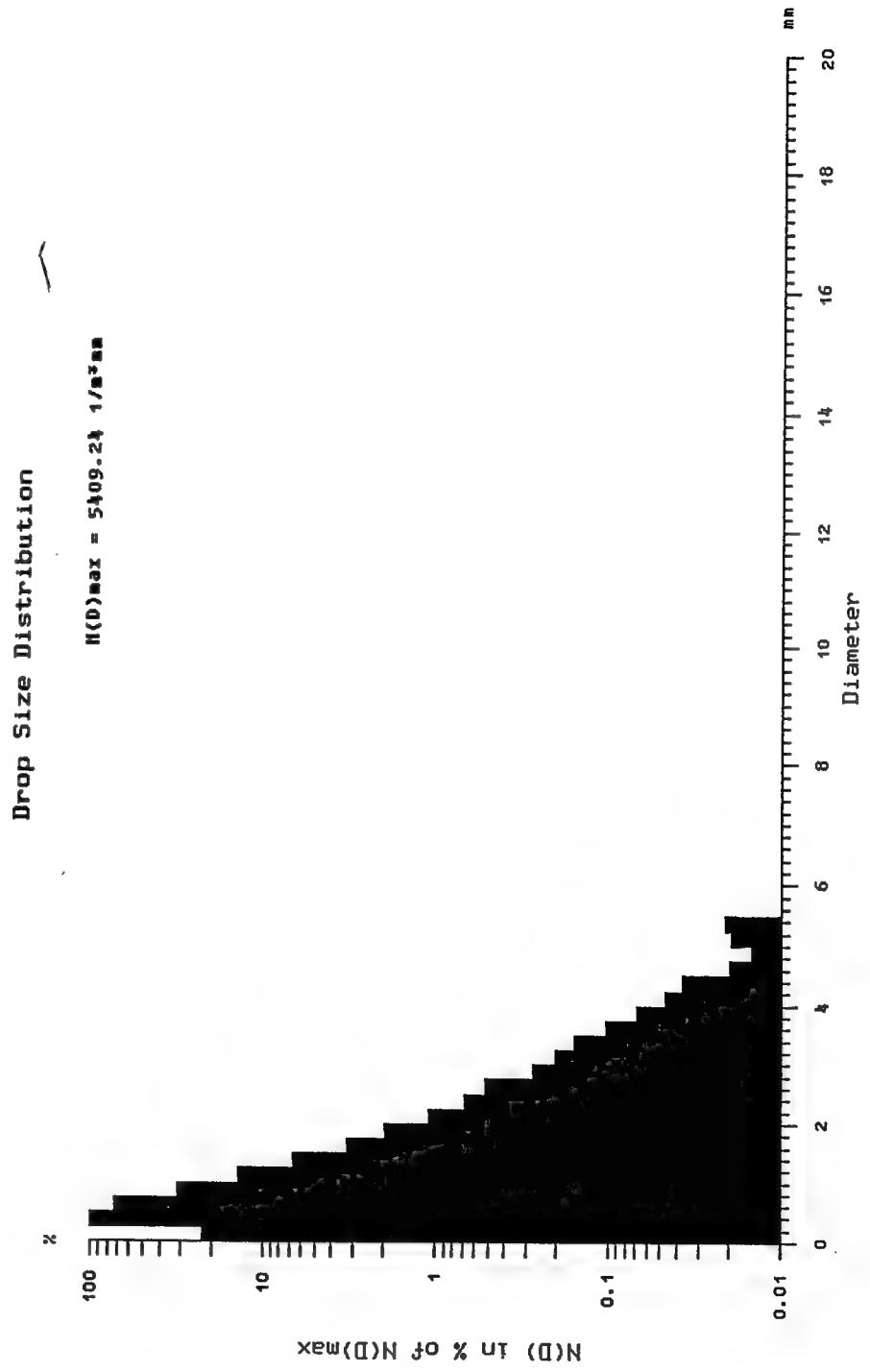
Contents: Watered covered ice particles  
Heavy rain with big drops  
14:36- Large hail (marble-sized) with  
very heavy  
14:44- Heavy winds to the northwest

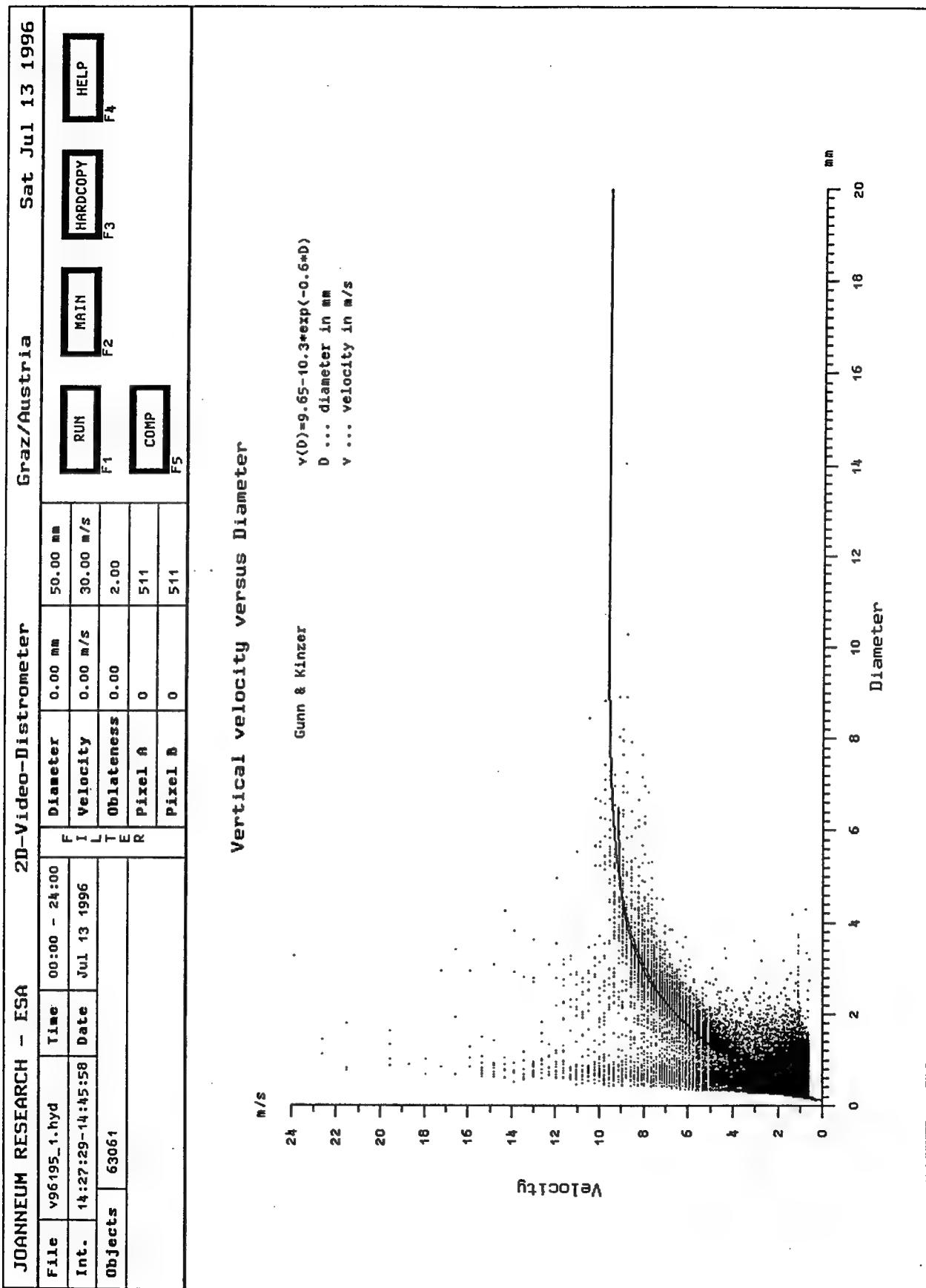
JOANNEUM RESEARCH – ESA						2D-Video-Distrometer						Graz/Austria						Sat Jul 13 1996						
File	906195_1.hyd	Time	14:00	–	15:00	F	Diameter	0.00	mm	50.00	mm	RUN	MAIN	HELP										
Int.	14:27:29 – 14:50:06	Date	Jul 13 1996		I	Velocity	0.00	m/s	30.00	m/s	F1	F2	HARDCOPY	F3										
			L	Oblateness	0.00	T	2.00							E										
			R	Pixel A	0	P	514							R	SCALE >	TIP								
				Pixel B	0		514							F5	SCALE <	Integr.	F7							
														F6			F8							
Rain	8.70 mm																							

Rainrate versus Time



JOANNEUM RESEARCH - ESA						2D-Video-Distrrometer						Graz/Austria						Sat Jul 13 1996						
File	V96195_1.hyd	Time	14:27 - 15:00	F	Diameter	0.00 mm	50.00 mm	RUN	MAIN	F1	HELP	F2	F3	HARDCOPY	F4	F5	AD <	AD >	F6	F7	F8	COMP		
Int.	14:27:00-14:50:00	Date	Jul 13 1996	I	Velocity	0.00 m/s	30.00 m/s																	
Rain	8.70 mm			L	Oblateness	0.00	2.00																	
Time Int	1380.00 s	Rainrate	22.70 mm/h	R	Pixel A	0	511																	
Objects	64154	AD	0.25 mm	Pixel B	0	511																		





Date: July 24, 1996

Julian Day: 206

Event: 1

Time: 18:21-18:35

Average Rain Rate: 24.93mm\hr

Total Rainfall: 5.96mm

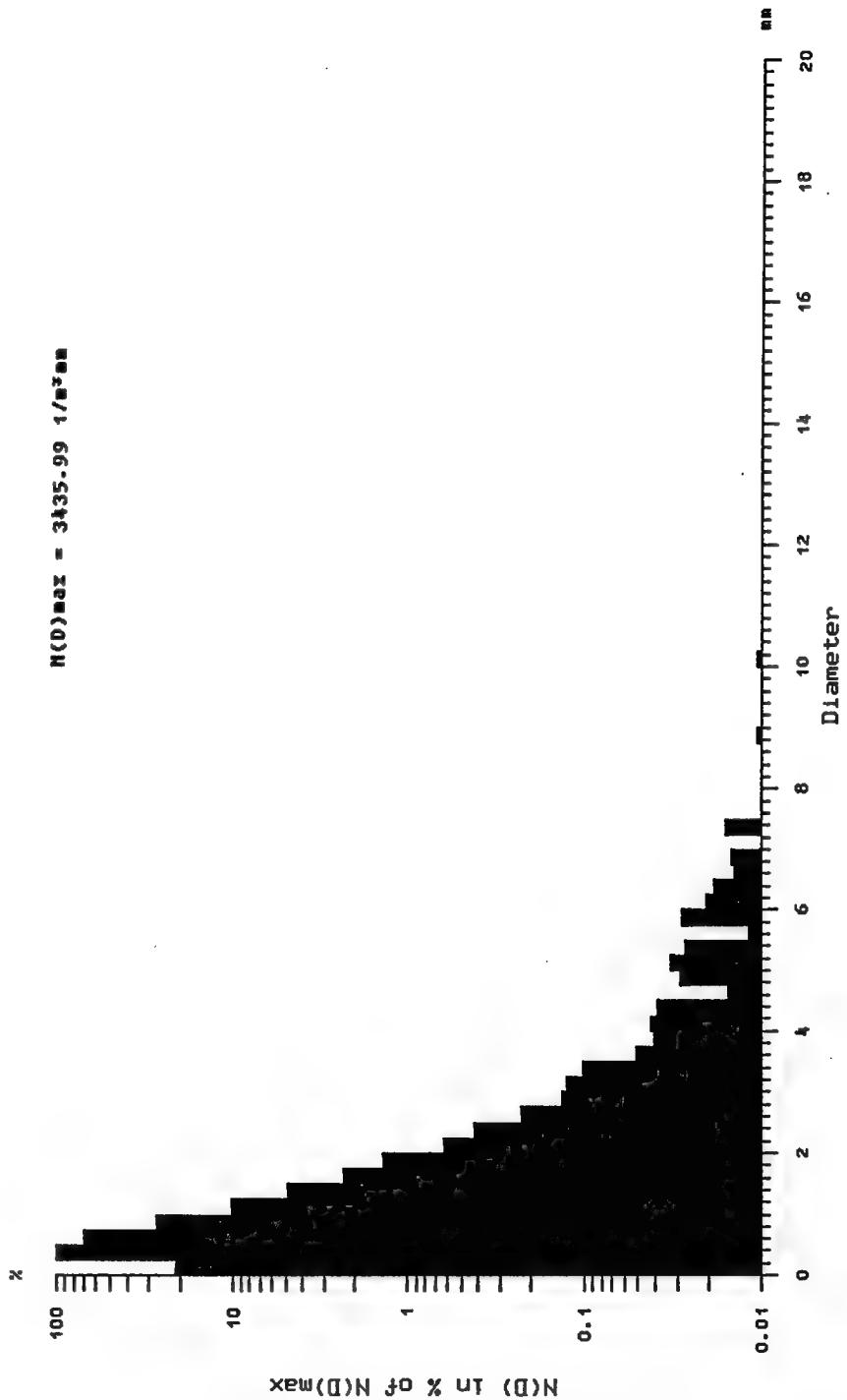
Location: Lat.- 40:42:42  
Lon.-104:54:13

Contents: Very little rain during hail event  
Pea to marble-sized hail

JOANNEUM RESEARCH - ESA										2D-Video-Distrrometer										
File	v96206_1.hyd		Time	18:21 - 19:00		Diameter	0.00 mm		50.00 mm		Graz/Austria									
Int.	18:21:00-18:35:20		Date	Jan 1 1970		Velocity	0.00 m/s		30.00 m/s		RUN		MAIN		HELP					
Rain	5.96 mm					Oblateness	0.00		2.00		F1		F2		F4		HARDCOPY			
Time Int	860.00 s		Rainrate	24.93 mm/h		Pixel A	0		511								F3			
Objects	21310		AD	0.25 mm		Pixel B	0		511		F5		F6		F8		AD >		Integr.	

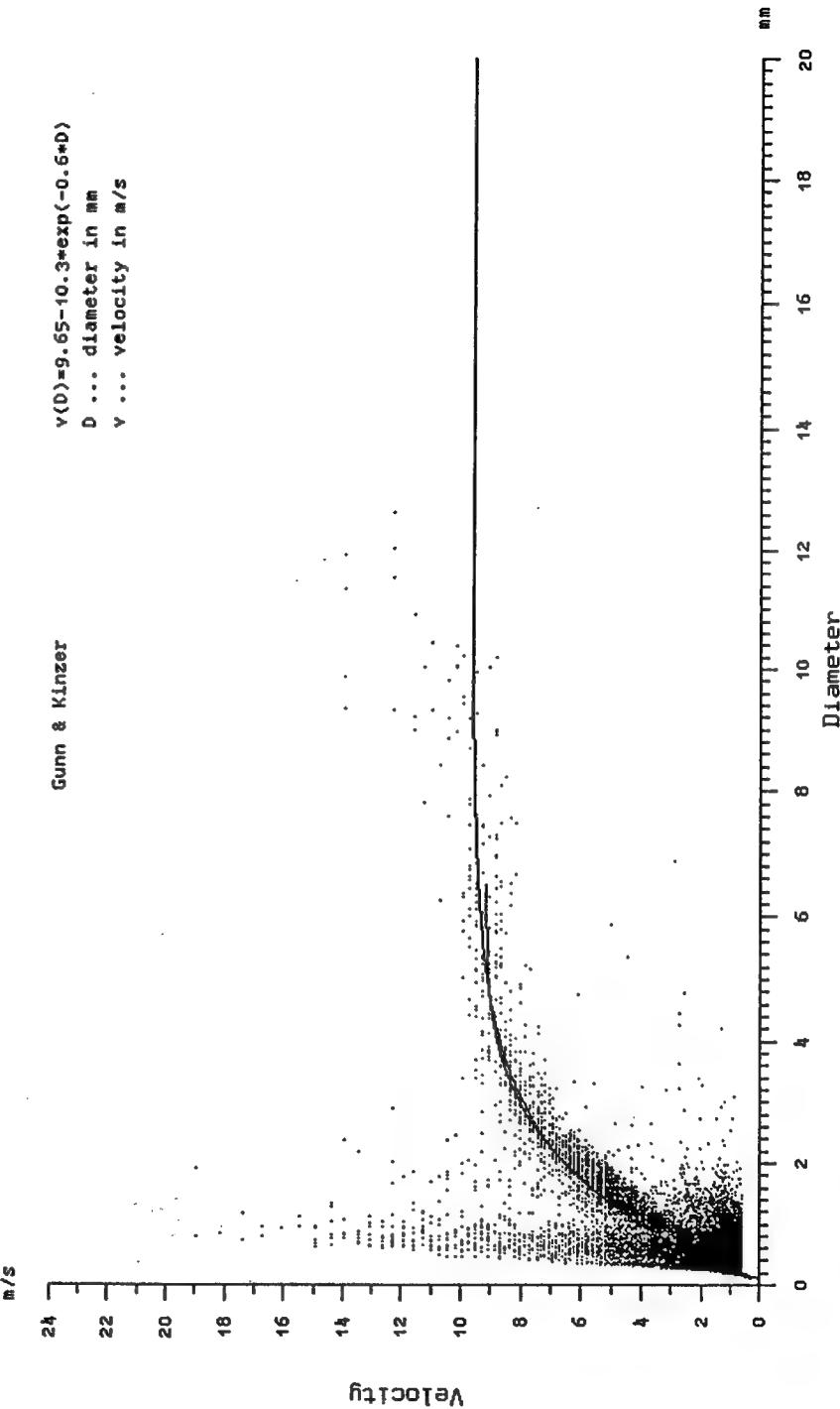
### Drop Size Distribution

$$N(D)_{\text{max}} = 3435.99 \text{ 1/mm}^3$$



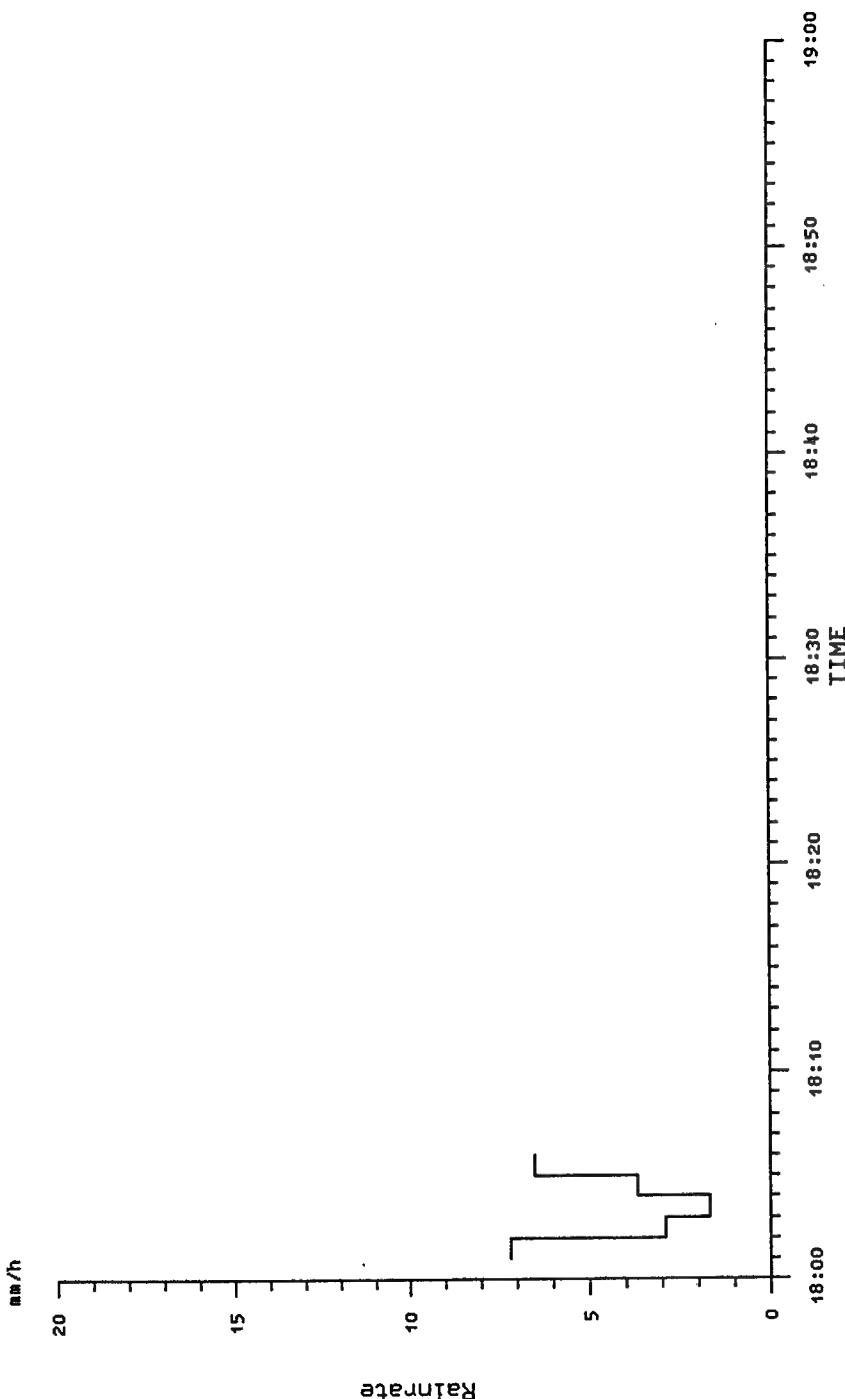
JOANNEUM RESEARCH - ESA						2D-Video-Distrometer			Graz/Austria			Thu Jan 1 1970		
File	v96206_1.hyd		Time	18:00 - 19:00		F	Diameter	0.00 mm	50.00 mm					
Int.	18:21:22-18:35:32		Date	Jan 1 1970		I	Velocity	0.00 m/s	30.00 m/s					
Objects	21318					T	Oblateness	0.00	2.00					
						E								
						R	Pixel A	0	511					
							Pixel B	0	511					

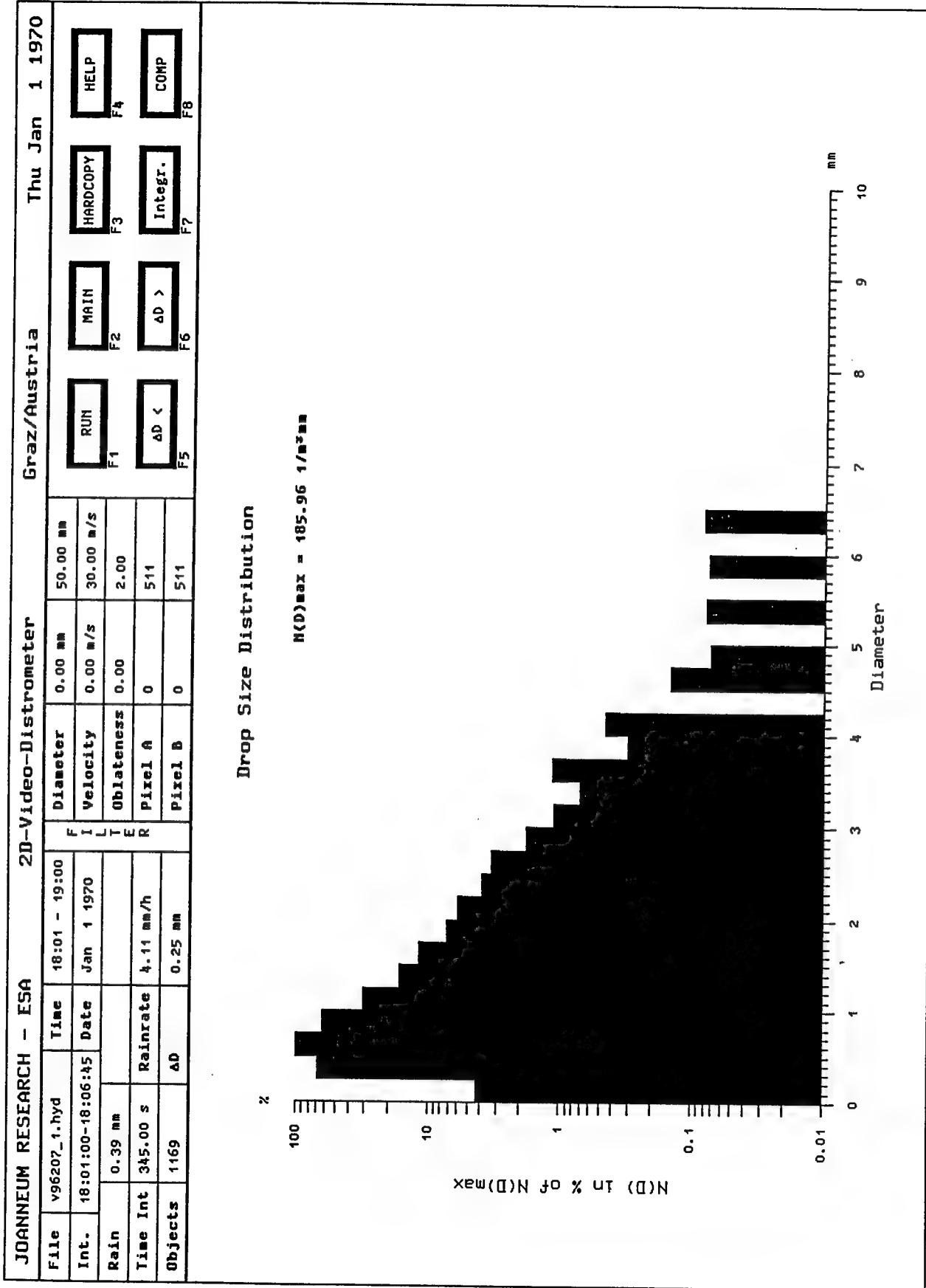
Vertical velocity versus Diameter



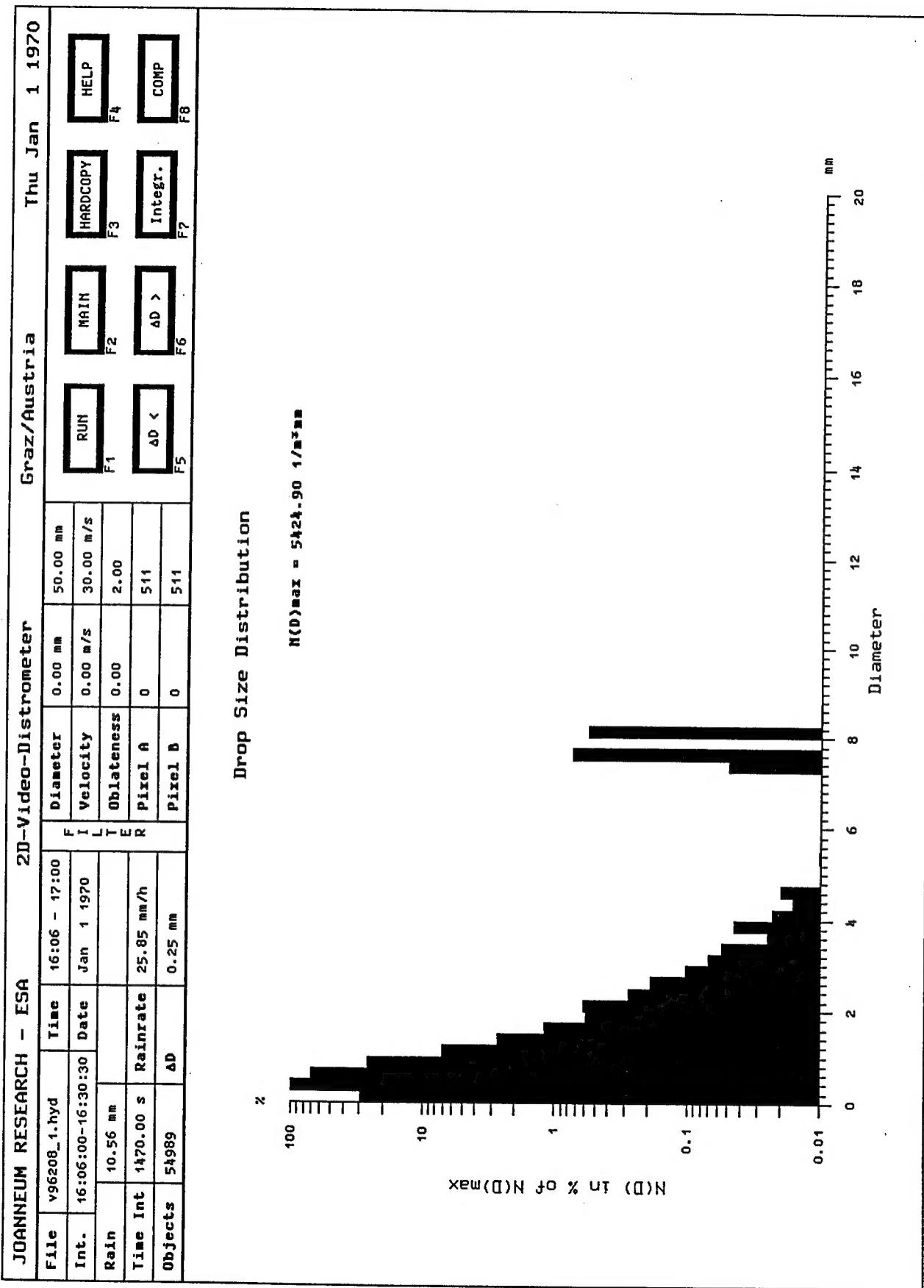
JOANNEUM RESEARCH - ESA						2D-Video-Distrometer						Graz/Austria						Thu Jan 1 1970						
File	v96207_1.hyd	Time	18:00 - 19:00	F	Diameter	0.00 mm	50.00 mm					RUN	MAIN											
Int.	18:01:00-18:06:50	Date	Jan 1 1970	I	Velocity	0.00 m/s	30.00 m/s					F1	HARDCOPY											
				L	Oblateness	0.00	2.00					F2	HELP											
Int. Mode	Time (60 sec)			E	Pixel A	0	511					F3												
Rain	0.39 mm			R	Pixel B	0	511					F4	SCALE <	Integr.										
								F5	SCALE >	F6	F7	F8												

Rainrate versus Time





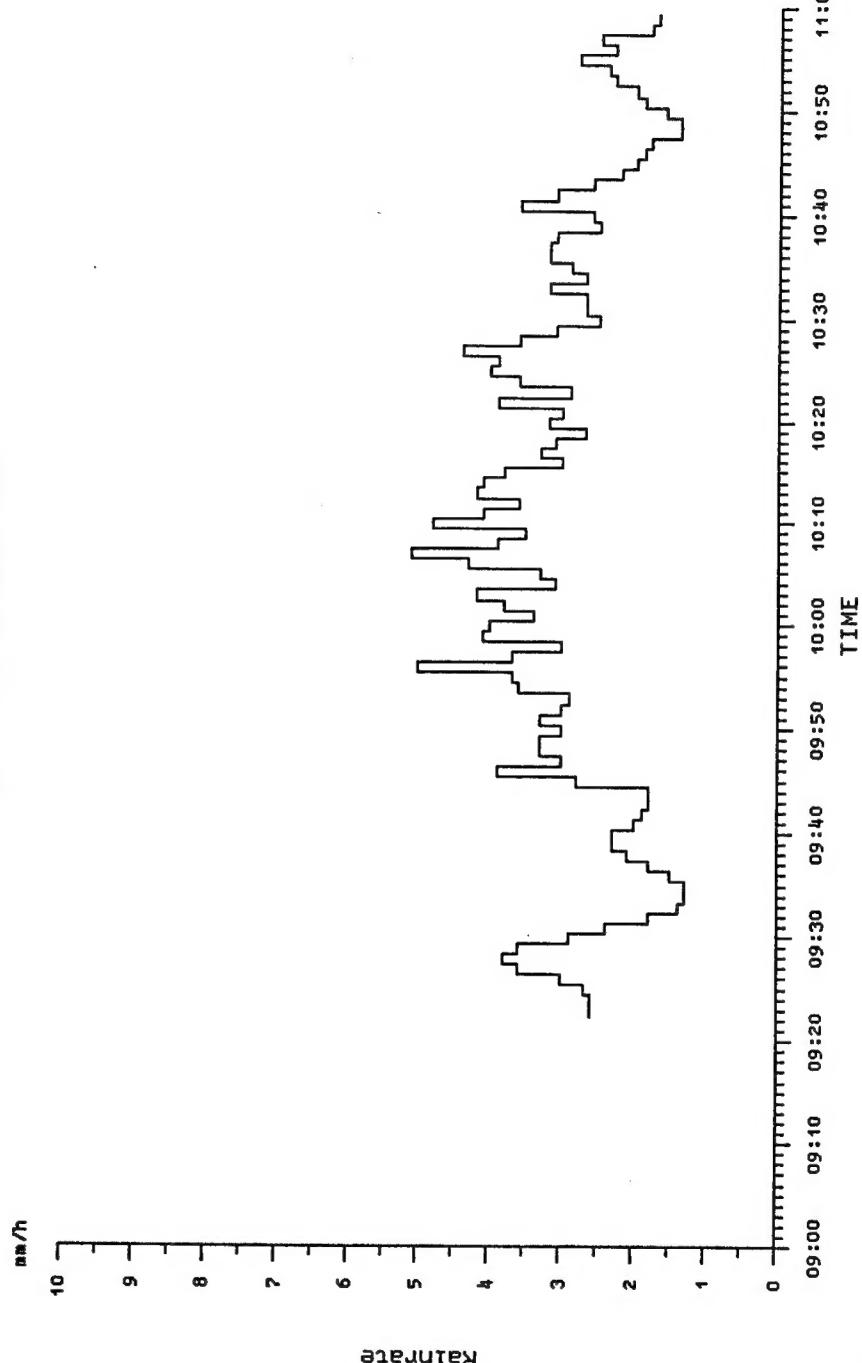




Date: July 29, 1996  
Julian Day: 211  
Event: 1  
Time: 9:22-11:05  
Average Rain Rate: 3.16mm\hr  
Total Rainfall: .25mm  
Location: EE parking lot  
Lat.- 40:34:35  
Lon.-105:05:0  
Contents: Moderate rain  
Rain had a widespread  
Very constant  
Large drops around 10:00  
Lighter rain towards the end  
Van scans

JOANNEUM RESEARCH - ESA						2D-Video-Distrometer			Graz/Austria		
File	v96211_1.hyd	Time	09:22 - 11:00	Diameter	0.00 mm	50.00 mm	MAIN	HELP	Wed Mar 18 1970		
Int.	09:22:22-10:59:59	Date	Mar 18 1970	Velocity	0.00 m/s	30.00 m/s	RUN	HARDCOPY			
				Oblateness	0.00	2.00	F1	F3			
				Pixel A	0	511					
				Pixel B	0	511	SCALE <	Integr.			
Rain	4.86 mm						F5	F7			
							F6	F8			

Rainrate versus Time



## **MISSION OF ROME LABORATORY**

**Mission.** The mission of Rome Laboratory is to advance the science and technologies of command, control, communications and intelligence and to transition them into systems to meet customer needs. To achieve this, Rome Lab:

- a. Conducts vigorous research, development and test programs in all applicable technologies;
- b. Transitions technology to current and future systems to improve operational capability, readiness, and supportability;
- c. Provides a full range of technical support to Air Force Material Command product centers and other Air Force organizations;
- d. Promotes transfer of technology to the private sector;
- e. Maintains leading edge technological expertise in the areas of surveillance, communications, command and control, intelligence, reliability science, electro-magnetic technology, photonics, signal processing, and computational science.

The thrust areas of technical competence include: Surveillance, Communications, Command and Control, Intelligence, Signal Processing, Computer Science and Technology, Electromagnetic Technology, Photonics and Reliability Sciences.